Atlas of important habitat for key fish species of the Scotian Shelf, Canada

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Abstract

Habitat information is critical to the process of protecting any species. On the Scotian Shelf, several fish species have been identified as key and influential components of the ecosystem. We evaluated important habitat for many of these key species by assessing the persistence of relatively high observed biomass in space and time using summer research trawl survey data. We propose that in general areas persistently ranked high are important habitat for these species.

Résumé

L'information sur l'habitat est un élément crucial du processus de protection de toute espèce. Plusieurs espèces marines présentes sur le plateau néo-écossais sont considérées comme étant des composantes essentielles et influentes de l'écosystème. Nous avons cerné l'habitat important d'un bon nombre de ces espèces importantes en évaluant la persistance, dans le temps et dans l'espace, des biomasses relativement hautes observées dans le relevé scientifique au chalut effectué l'été. Nous proposons que de façon générale les zones où la biomasse des espèces susmentionnées est considérée comme étant élevée de façon persistante soient considérées comme un habitat important pour ces espèces.

1.0 Introduction

In 1997, Canada's Oceans Act was passed to provide a statutory framework for a national oceans management strategy based on the principles of sustainable development, integrated management and the precautionary approach. There are several pilot projects for integrated ocean management across Canada that are developing plans to manage the multiple human activities occurring in the marine environment and to achieve precautionary conservation goals and a framework for sustainable ocean use and development. As part of a broad and detailed process, members of the Stakeholder Advisory Council for the Eastern Scotian Shelf Integrated Management (ESSIM) area developed a set of objectives under their identified goal for "Healthy Ecosystems". These strategic objectives are based both on ecological process and species. The species-based conservation objectives broadly stated, are to ensure that key species are not "perturbed by human activities to the point where [they] are unable to fulfill their role within the ecosystem" (DFO 2007a). Of course, habitat information is critical to the process of protecting any species. On the Scotian Shelf, several fish species have been identified as key and influential components of the ecosystem, based on ecosystem modelling (Bundy 2005). This atlas was prepared by the Oceans and Coastal Management Division to provide contemporary regional information on the areas of importance during the summer for key species on the Scotian Shelf, Canada.

1.1 How is important habitat defined?

There is a vast amount of information on the life history and habitat requirements of Atlantic Canada fish species (e.g. Simon and Comeau 1994; Breeze *et al.* 2002; Scott and Scott 1988; Mahon *et al.* 1998). The problem is the information can be overly general, not spatially explicit or cannot be applied on a regional scale. Conservation biologists will often test for "density-dependent geographic distribution" which means that animals expand their range when their densities increase, as has been observed in many taxa (Gaston and Blackburn 2000). This is related to the theory that animals will occupy habitat that maximizes their fitness ---if there are too many animals in an optimal habitat, the resources per individual decline, so some animals will benefit by moving to marginal habitat (Fretwell and Lucas, 1970, MacCall 1990).

In Atlantic Canada, there has been considerable effort to identify important habitat for marine fish by testing whether fish expanded their range when the population expanded (e.g. Myers and Stokes 1989; Marshall and Frank 1994; Swain and Sinclair 1994; Swain and Morin 1996; Frank and Fisher 2004, Shackell *et al.* 2005). The results varied across studies—not all species conformed to expectations but important insight was gained. Animals will not expand their range when their population increases if:

1) population abundance does not vary (no expansion will be detected);
2) the preferred habitat is unsaturated;
3) the species requires a specific but limited type of habitat;
4) habitat selection changes over time or with age;
5) fishing was concentrated on high-density areas which were not replenished fast enough. That means that areas occupied by severely depleted species may not reflect the historical array of important habitat.

We based our approach on the factors listed above. We adopted a method which would be independent of changes in abundance. As well, we divided the summer time series into fishery management eras in order to detect whether a high-density area had been abandoned due to a severe population decline as a result of directed fishing. In effect, we adopted a simple and practical approach that assumes that summer is a time of rapid growth and feeding, and that summer habitat is important to a species if it is found there consistently in higher concentrations.

In the Atlantic Canada region, there are a variety of related initiatives contributing to the development of integrated management that will find these maps useful. However, the maps should be interpreted in the context of the status of the population (also included). For example, we recommend a precautionary approach that assumes the existence of low-mixing populations that can be differentially affected by fishing. For species at risk, only those maps derived before significant population declines should be used to identify high-density areas. Such areas would represent those with the potential to support higher densities as well as the historical array of subpopulations (Shackell *et al.* 2005).

2.0 Methodology:

2.1 Key Species

The identification of "ecologically significant species and community properties" (DFO 2006) and conservation objectives for large ocean management areas (LOMAs), such as the eastern Scotian Shelf, (DFO 2007b) was a requirement in support of Ocean Action Plan Phase 1 (DFO 2005). Ecologically significant species (ESS) and community properties were categorized under four types: 1) species with a potentially controlling influence on the ecosystem structure or function, such as species with significant trophodynamic roles (e.g. influential predators, forage species); 2) structure providing species; 3) aggregate ecosystem properties above the species level; and 4) species which could pose a particular threat to the ecosystem (e.g. invasive species) (DFO 2006). We focused our effort on the identification of important habitat for species that are regularly observed in scientific trawl surveys and that were identified as type 1 (i.e., influential predators and forage species) in the Maritimes region. We also include species that were identified as "depleted" based on their status from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) based on guidance for the establishment of conservation priorities within LOMAs (DFO 2007b). In our region some "depleted" species, such as Spotted and Northern Wolffish, may currently be at the limit of their natural range and their status is debatable. Nonetheless, they were included in the "depleted" category to maintain consistency with the COSEWIC designation. The species evaluated in this report are identified in Table 1 by both their common and scientific names, and by grouping (i.e. ESS, depleted, etc). The COSEWIC listing status is indicated in parantheses next to the common name for depleted species. Nine additional species that are dominant (i.e., occur in > 10% of all trawl sets) in the summer research vessel trawl surveys have also been included (Table 2).

Table 1. Ecologically significant and depleted (or rare) species of the Scotian Shelf Large Ocean Management Area (LOMA).

Scientific Name	Common Name	Group
Mallotus villosus	Capelin	ESS – Type 1, Forage Species
Clupea harengus	Herring	ESS – Type 1, Forage Species
Scomber scrombus	Mackerel	ESS – Type 1, Forage Species
Ammodytes dubius	Sandlance	ESS – Type 1, Forage Species
Illex illecebrosus	Shortfin Squid	ESS – Type 1, Forage Species
Glyptocephalus cynoglossus	Witch Flounder	ESS – Type 1, Forage Species[1]
Merluccius bilinearis	Silver Hake	ESS – Type 1, Influential Predator

[1] While this species was identified as a forage species, there is conflicting information about its role as a forage species based on information available from stomach analyses in the region (J. Simon, pers. comm.). Nonetheless, this species meets our criteria as a dominant species in the region.

Hippoglossoides platessoides	American Plaice	ESS – Type 1, Influential Predator
Gadus morhua	Atlantic Cod (special concern)	ESS – Type 1, Influential Predator & Depleted Species
Melanogrammus aeglefinus	Haddock	ESS – Type 1, Influential Predator
Hippoglossus hippoglossus	Atlantic Halibut	ESS – Type 1, Influential Predator
Myoxocephalus octodecemspinosus	Longhorn Sculpin	ESS – Type 1, Influential Predator
Pollachius virens	Pollock	ESS – Type 1, Influential Predator
Urophycis chuss	Red Hake	ESS – Type 1, Influential Predator
Sebastes spp.	Redfish	ESS – Type 1, Influential Predator
Malacoraja senta	Smooth Skate	ESS – Type 1, Influential Predator
Squalus acanthias	Dogfish	ESS – Type 1, Influential Predator
Urophycis tenuis	White Hake	ESS – Type 1, Influential Predator
Leucoraja ocellata	Winter Skate (threatened / special concern)	ESS – Type 1, Influential Predator & Depleted Species
Brosme brosme	Cusk (threatened)	Depleted Species
Anarhichas denticulatus	Northern Wolffish (threatened)	Depleted Species
Anarhichas minor	Spotted Wolffish (threatened)	Depleted Species
Anarhichas lupus	Atlantic Wolffish (special concern)	Depleted Species

Table 2. Additional Dominant Species Observed in Summer Trawl Surveys

Scientific Name	Common Name
Triglops murrayi	Mustache Sculpin
Amblyraja radiata	Thorny Skate
Limanda ferruginea	Yellowtail Flounder
Lophius americanus	Monkfish
Hemitripterus americanus	Sea Raven / Sea Sculpin
Zoarces americanus	Ocean Pout
Pseudopleuronectes americanus	Blackback / Winter Flounder
Argentina silus	Atlantic Argentine
Phycis chesteri	Longfin Hake

2.2 Identifying Important Habitat

We asked whether there were areas of consistently high(er) biomass despite changes in ecological/environmental characteristics and fishery management influences. We used ArcGIS® software for the analyses and display.

2.2.1 Summer Research Vessel Survey

Since 1970, the Department of Fisheries and Oceans (DFO) has conducted a summer research vessel (RV) survey on the Scotian Shelf in Atlantic Canada to assess the distribution and abundance of both commercial and non-commercial species. The survey uses a stratified random sampling design. Forty-eight strata are defined by geographic location and uniform depth (Figure 1). Samples (sets) are allocated to each stratum in proportion to its area. Each set consists of the deployment of a standard, Western IIA bottom trawl with a 19 mm codend liner. The surveys used a #36 Yankee bottom trawl from 1970 to 1981 and a Western IIA trawl since 1982. The trawl is towed at a constant speed of 3.5 knots for approximately 30 minutes. The total swept area of one set is 0.0404 km^2. The survey is conducted around the clock, randomly within strata and among years during the month of July (Simon and Comeau, 1994). In the early 1970s, several sets were taken in the Gulf of St. Lawrence, outside of the main domain.

The survey data were not corrected for differences in catchability among species. However, invertebrates were not routinely measured, and if they were (e.g. lobster), their catchability is considered to be less than that of finfish (J. Simon, DFO, pers. comm.). In addition, earlier in the time series, Red Hake was sometimes misidentified. As well, there was earlier confusion in differentiating little and Winter Skates. In both cases, the magnitude of misidentification cannot be quantified.

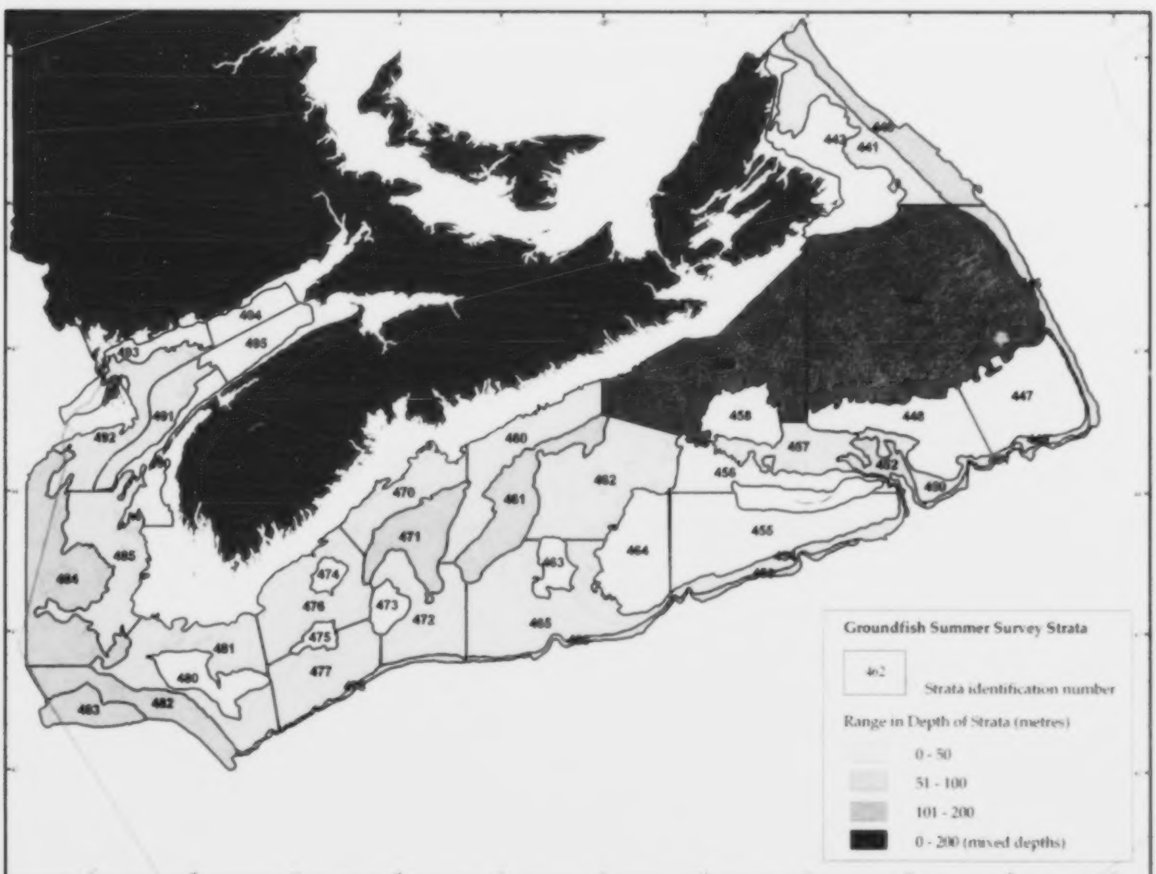


Figure 1. Map of research vessel (RV) survey strata in the Maritimes Region.

2.2.2 Definition of Time Blocks

Our first step was to divide the time series into 4 periods, roughly corresponding to fishery management eras. Note that the divisions are similar to the 5-year time blocks used by Simon and Comeau 1994. The eras are:

1. 1970-77- represents a period when foreign fleets were active in Canadian waters;
2. 1978-85: Establishment of the 200 mile limit, (Exclusive Economic Zone) and subsequent recovery of domestic stocks before domestic fishery was fully engaged;
3. 1986-93: domestic fleets increased fishing pressure, combined with colder waters on the eastern Scotian shelf, decline in growth rate and collapse of some fish stocks;
4. 1994-2006: collapse and non-recovery of several groundfish species on the eastern Scotian shelf.

2.2.3 Interpolation Method of Spatial Data

For each species in our study the observed weight per tow, hereafter referred to as biomass, including null values, were interpolated across the sampled area using the inverse distance weighting (IDW) technique in ArcGIS®. This method was applied for each of the four time blocks. For the interpolation we used a fixed search radius of 0.15 degrees (equivalent to approximately 14-15 kilometres for our study area) with an output cell size of 0.026177 degrees. The interpolation was optimized by the software (ArcGIS® Spatial Analyst, ESRI) for the spatial distribution of the data. The results of these interpolations are displayed as Maps 1 to 4 for each species in Section 3. The following map (Figure 2) shows the trawl survey locations for the years from 1970 to 2006, inclusive, and is provided only to assist the reader in visualizing the extent of the interpolation window relative to the available data.

Figure 2. Map shows a 0.15 degree grid cell (blue squares) relative to the location of the trawl sets during the period from 1970 to 2006 (inclusive).

IDW is an interpolation technique that fits the source data accurately and preserves local anomalies in the interpolation grid. In contrast, Kriging techniques assume the source data have regionalized errors of

estimation and generalize the data to minimize estimation variance. Kriging tends to eliminate local anomalies from the interpolation grid to portray a more general trend for the data. For this exercise, we decided to use the technique that would preserve local anomalies where they are observed.

2.2.4 Mapping Procedure for the Identification of Important Habitat

We evaluated important habitat for each of the key species by assessing the persistence of relatively high observed biomass in space over the entire time period of the data. Relative biomass in each time period was assessed by classifying the interpolated distribution into 10 quantile breaks, where for example the 10^{th} class break represents the top 10% of areas where the species is observed. This method allows us to ignore population trends and simply determine, regardless of population status, where the areas of highest biomass are located. We propose that in general areas persistently ranked high are important habitat for these species. These areas were determined by using simple spatial algebra to combine the four time blocks for each species. Precedence for this type of analysis to identify important or critical habitat can be found in Keith (2005).

For each species, our procedure was as follows:

1. **Extracted data:** Data for each of the key species were extracted from the Summer RV Survey data (1970-2006), including null values.
2. **Interpolated data:** From this, Inverse Distance Weighted (IDW) interpolations of the observed weight for each species were created for four periods representing different fishery management regimes (1970-1977, 1978-1985, 1986-1993, 1994-2006) (Figure 3). Parameters for the IDW interpolation were as described in Section 2.2.3.
3. **Classified interpolated data into deciles:** Each of four maps for was classified into 10 percentile classes using the "Quantile breaks" ArcGIS® tool. Zero and null values were excluded from the classification. Note: The quantile breaks tool defines the breaks by area (i.e., of the total area where a species is observed).
4. **Assigned ranks:** The maps where then reclassified (ranked) with a value of 1 through 10; where 1 represents the observations in the 1^{st} decile (1-10^{th} percentile), 2 represents the 2^{nd} decile (11^{th}-20^{th} percentile), and so on up to 10 which represents areas with the 91^{st}-100^{th} ranked observations (Table 3) based on interpolation of the observed weight per tow.
5. **Summed ranks over time:** The four resulting ranked maps were added together to create a picture of the continuity of the area as important habitat for the species. So for example if an area had a score of 10 in each time block, the final score would be 40 (10+10+10+10 = 40) and reflect that a relative high biomass of that species had always been found in the area.

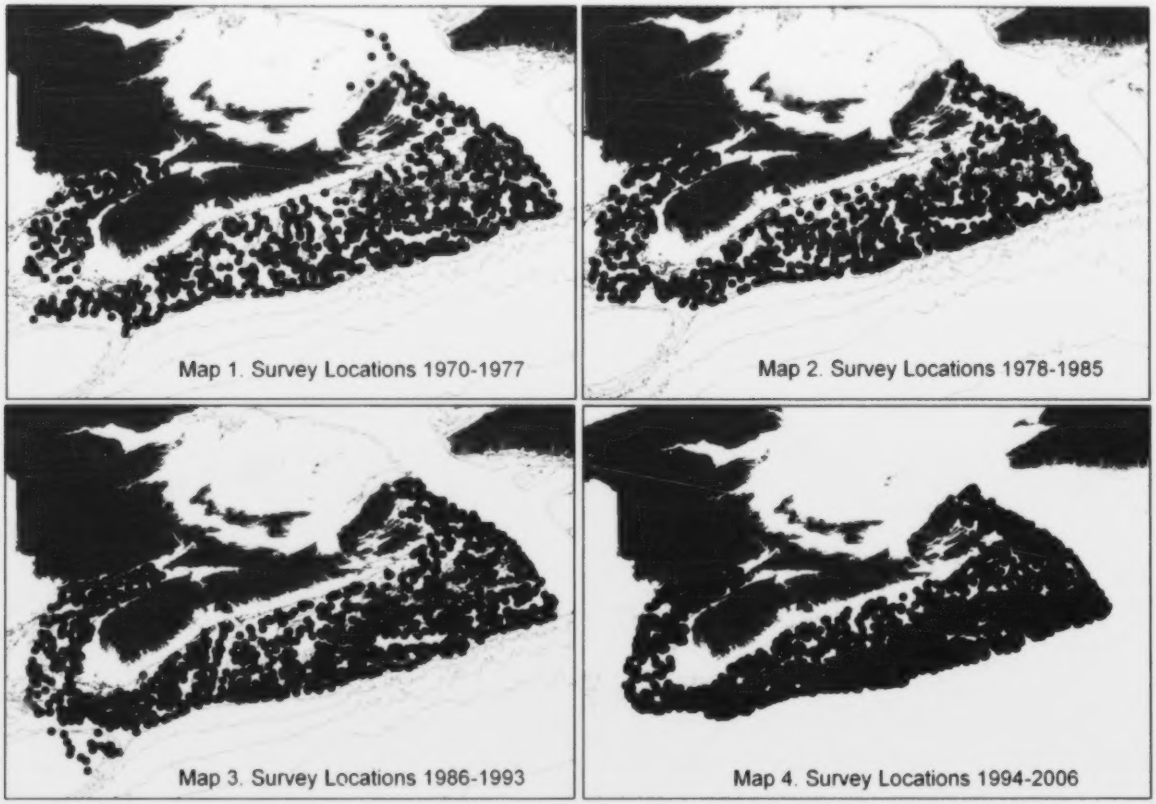


Figure 3. Map shows trawl set locations in the four time periods evaluated. Data for observed weight from these trawls were used in the interpolation of the observed weight for each species.

Table 3. Quantile Break Scores

Percentile	Score
<=10th	1
11-20th	2
21-30th	3
31-40th	4
41-50th	5
51-60th	6
61-70th	7
71-80th	8
81-90th	9
91-100th	10

Note that in each period the quantile break scores reflect the relative spatial distribution of biomass and not the absolute. This allows the reader to identify the areas where the species is consistently sampled regardless of absolute biomass. To assess the population status, the maps are accompanied by the temporal trend in biomass and abundance for each species.

2.3 Trends in the Trawl Survey Catch for Key Species

The stratified mean number per tow (abundance) and mean weight per tow (biomass) are shown on each species page as "Figure 1. Population Trends". Note that each y-axis is scaled to the data. Stratified estimates were extracted from the DFO Virtual Data Centre (http://marvdc.bio.dfo.ca/pls/vdc/mwmfdweb.splash).

2.4 Larval Fish Distributions

For comparison with the distribution of adult fish, when possible, we have included maps (Map 6 for each species) that indicate the distribution of larval fish from the SSIP data collected by DFO. For these maps the average number of individuals observed in a standardized volume is plotted. From these point data a fixed kernel density estimate was calculated using Hawth's Tools (Beyer 2008), a freely available software extension for ArcGIS® (http://www.spatialecology.com/htools/index.php). Subsequently the tool was used to plot contours that identify the percentage of the observed data, in our case 80% and 95% of the total number of individual larval fish.

2.4.1 Scotian Shelf Ichthyoplankton Programme (SSIP)

The data used in this study were collected on the Scotian Shelf from 1978 to 1982 as part of the SSIP. Only larval stage data from the original SSIP data set were used in our analyses. The SSIP was designed to collect temporal and spatial information about fish eggs and larvae on the Scotian Shelf. The survey used a standard sampling design on a transect grid. An oblique Bongo tow with a 333-mm-mesh net was typically deployed for around 30 min. The total volume filtered was measured by flowmeters attached to the Bongo net at tow depths that ranged from 23 to 247 m, averaging 112 m. The ranges of sampling depth were comparable across months. Samples stored in 5% formalin were identified and catalogued at the Huntsman Marine Laboratory, St. Andrew's, New Brunswick, Canada. Additional information on the SSIP survey design can be found in O'Boyle *et al.* (1984).

2.4.2 Mapping Procedure for Larval Fish

Larval fish from the SSIP data were mapped by sampling locations aggregating the sampling location to one eighth of a degree or 7.5 arc minutes of latitude and longitude. If SSIP data were available for the species of interest, we used a kernel density mapping tool to plot the 80% and 95% contours of total

observed abundance for the species. Hawth's Tools, which is an extension for ArcGIS® software, (http://www.spatialecology.com/htools/index.php) was used to perform this analysis.

3.0 Results – Important Habitat and Population Trends

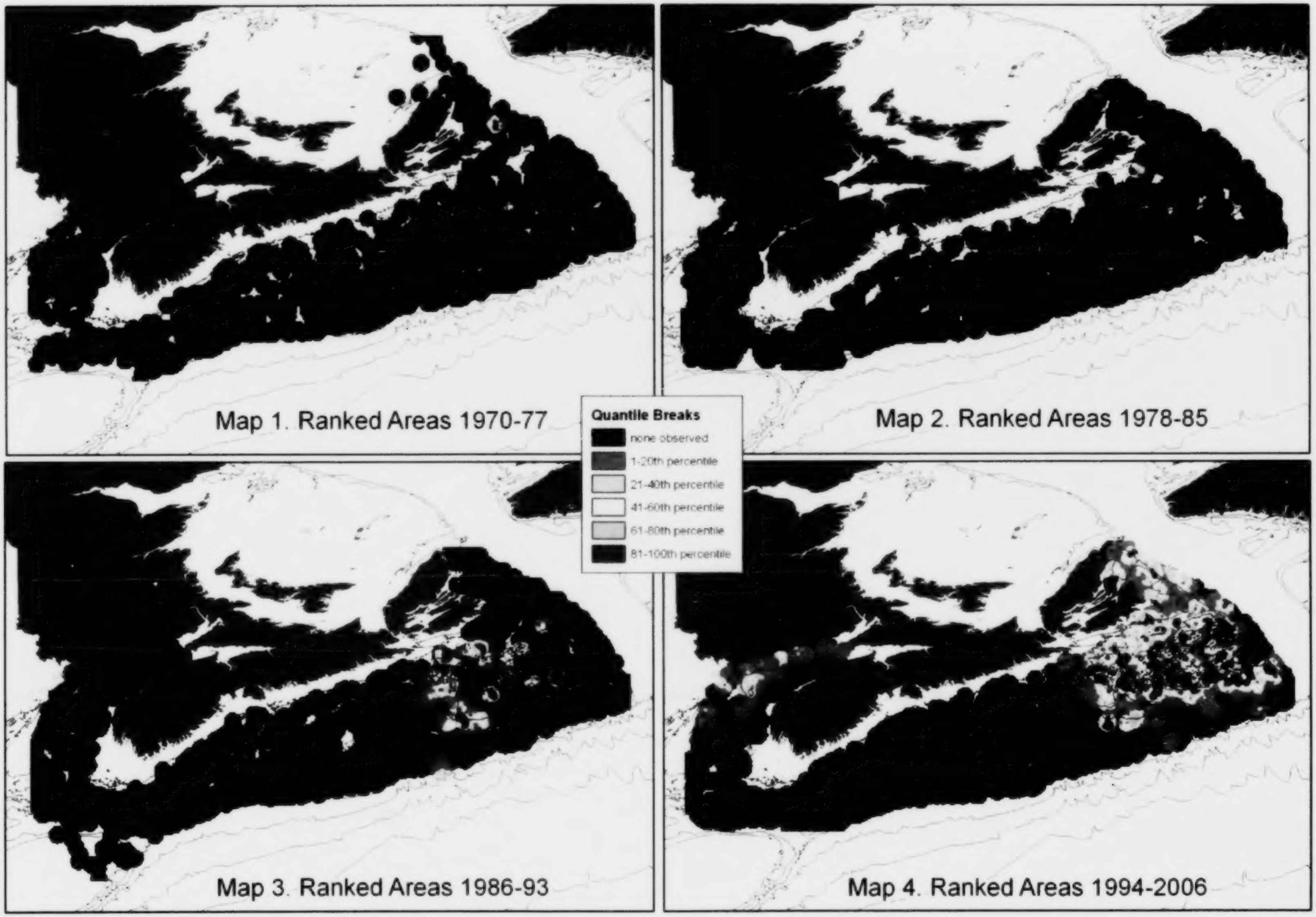
The following information describes how the maps of species distributions should be interpreted.

In each of the four time periods (Maps 1 to 4 for each species), areas where sampling occurred but where the species was not observed (within the search radius of the interpolation) are displayed in dark blue, whereas areas with no colour were not sampled (or within the search radius of the interpolation).

On the summed rank maps (Map 5 for each species) only areas where the species was observed appear. On these maps areas where the species was rarely observed are indicated in dark blue. Areas in dark orange to red on these maps are areas where the species has been observed in large amounts (biomass) in each of the four time periods.

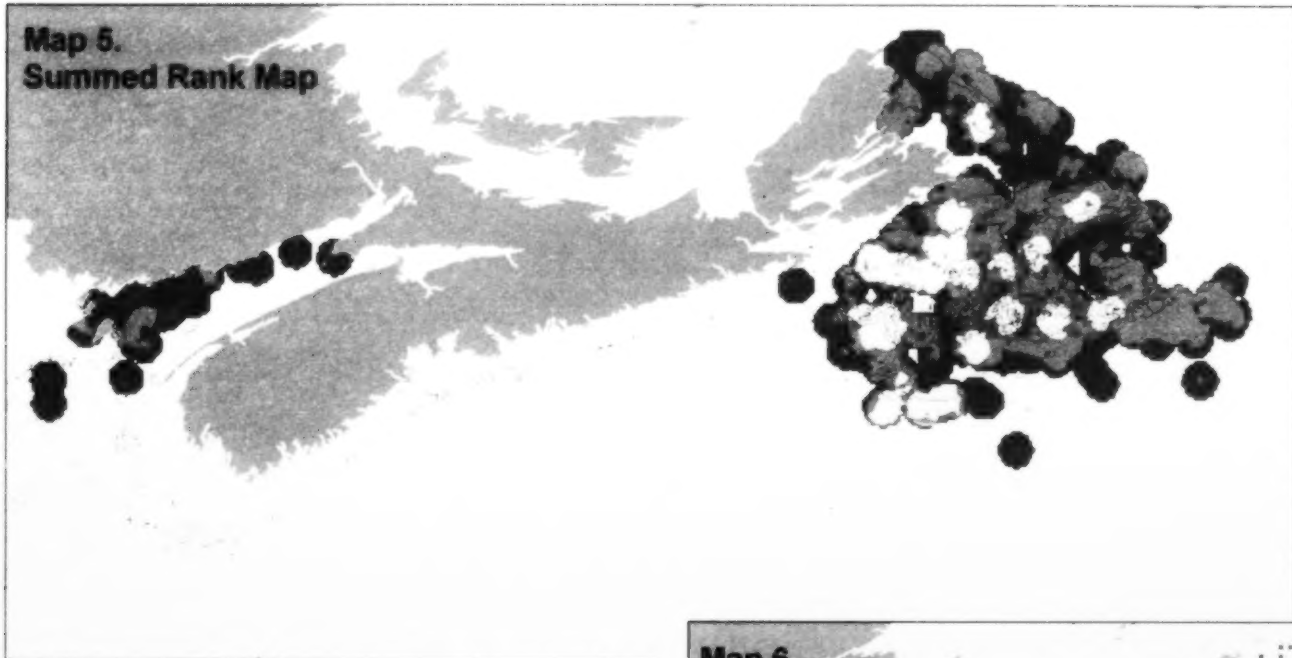
3.1 Forage Species

The results of our evaluation of areas of persistently high ranking biomass and population trends can be found on the following pages for the these species identified as important forage species for the Scotian Shelf: Capelin *(Mallotus villosus);* Herring *(Clupea harengus);* Mackerel *(Scomber scrombus)*; Sandlance *(Ammodytes dubius);* Northern Shortfin Squid *(Illex illecebrosus)*; Witch Flounder (*Glyptocephalus cynoglossus).*



Capelin (*Mallotus villosus*)

Capelin (*Mallotus villosus*)



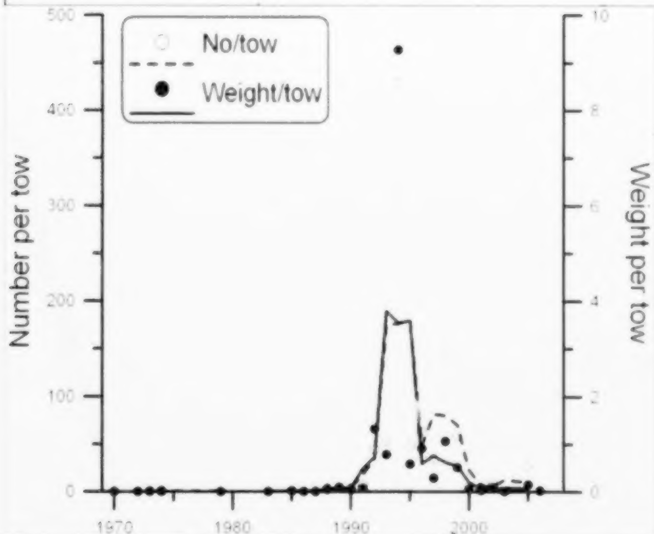
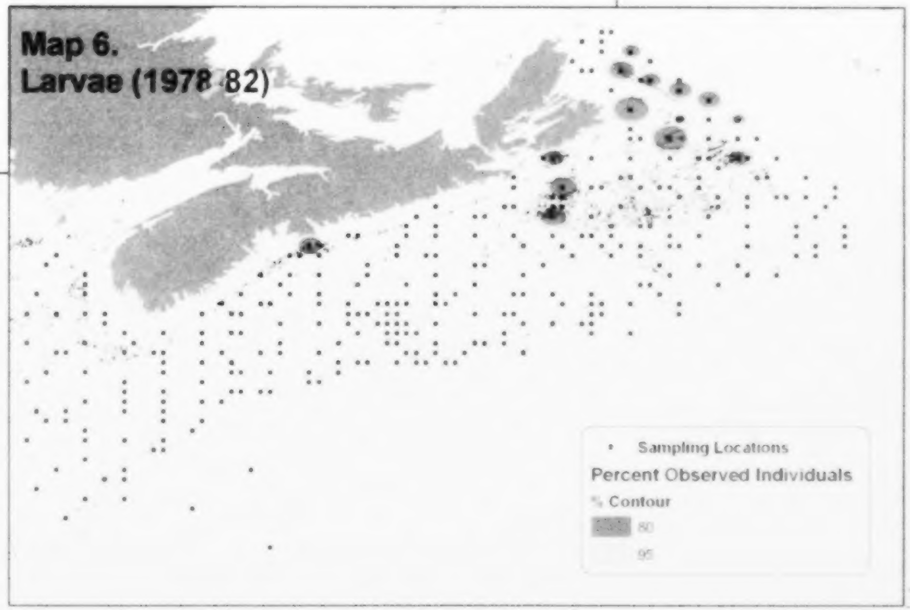


Figure 1. Population Trend



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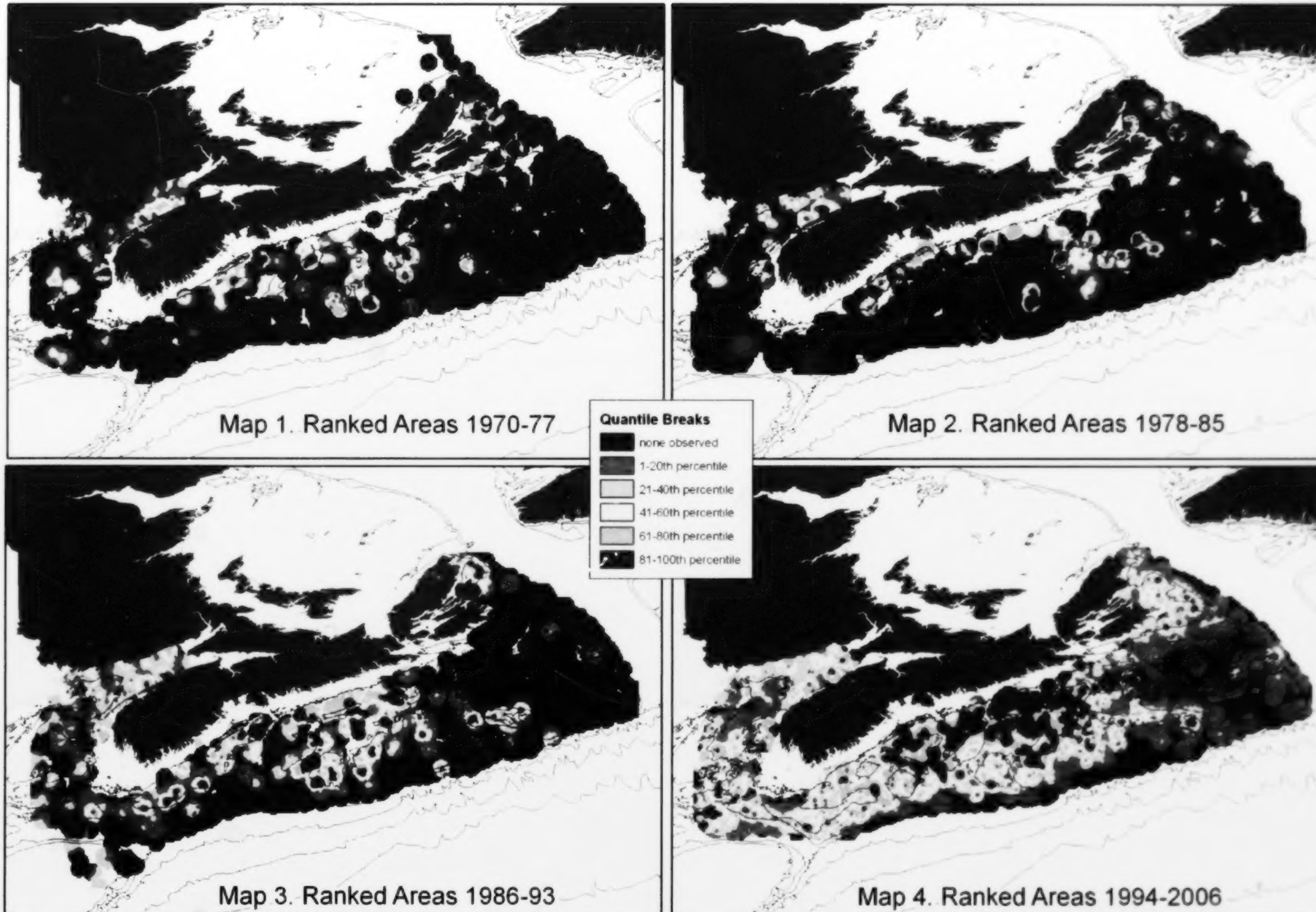
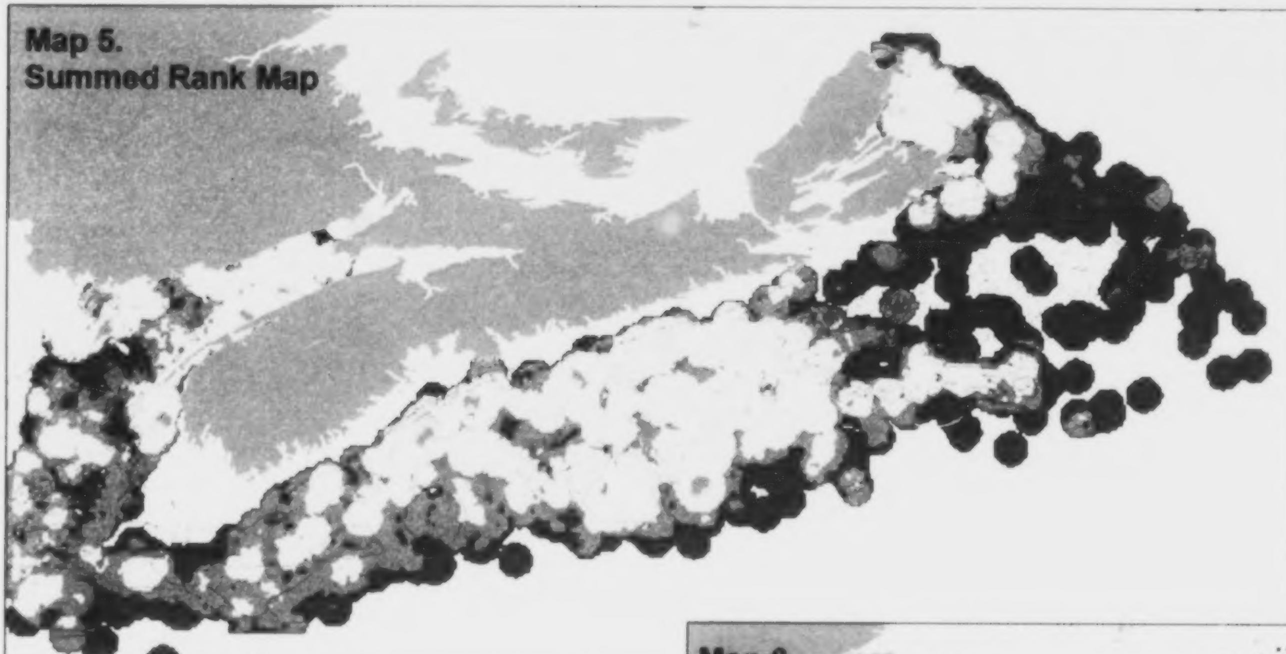


Herring (*Clupea harengus*)

Herring
(*Clupea harengus*)



Map 5.
Summed Rank Map

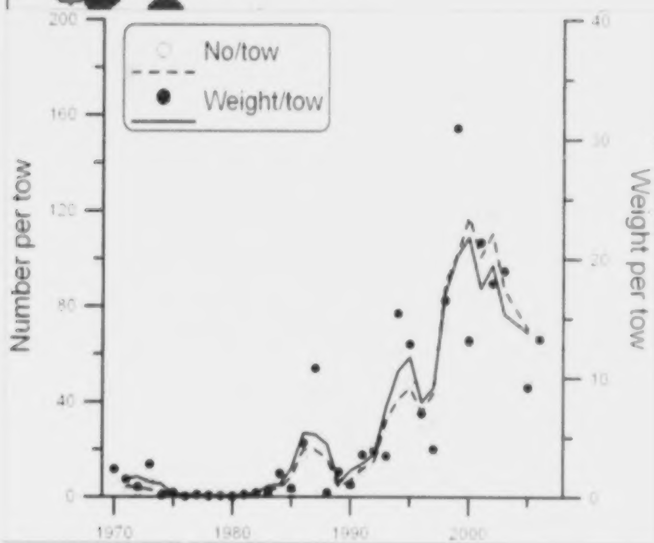
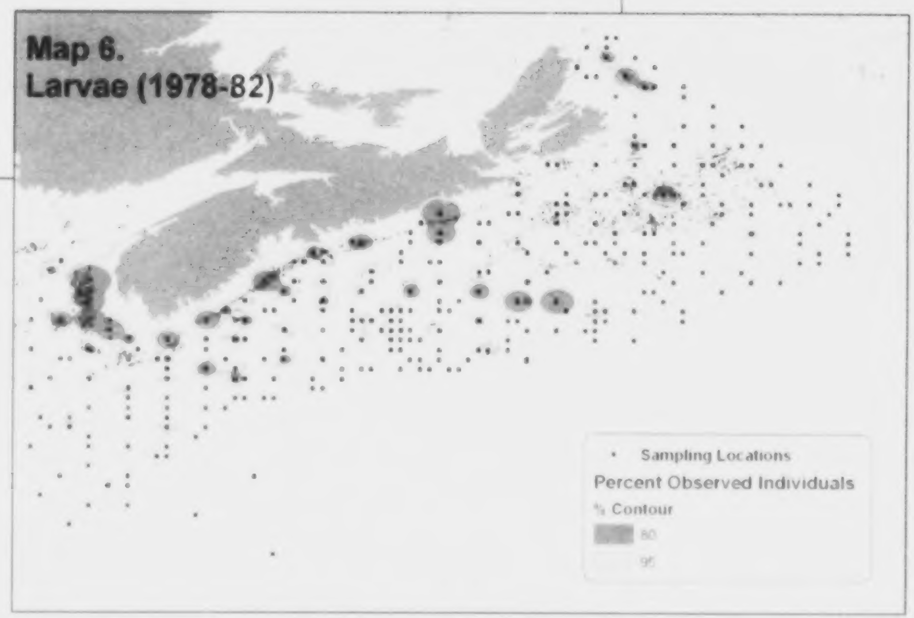
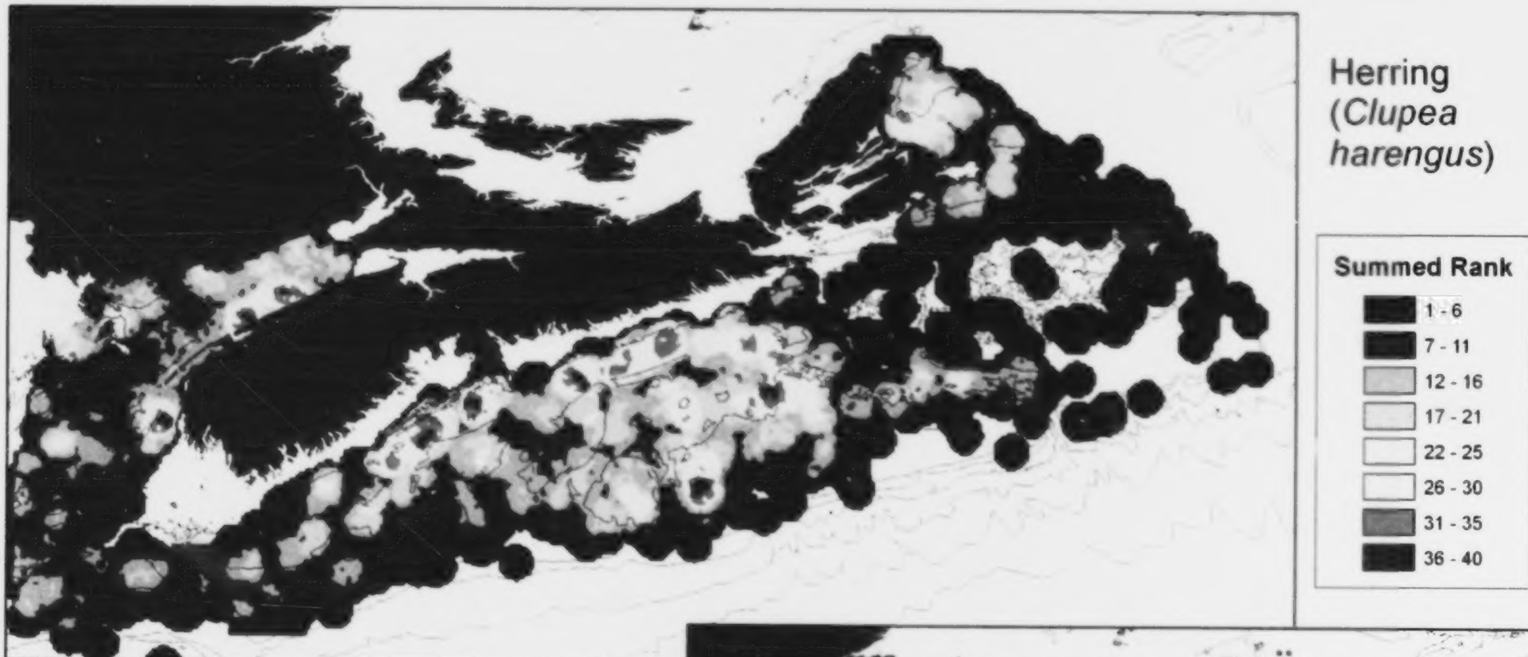


Figure 1. Population Trend



Map 6.
Larvae (1978-82)

Herring (*Clupea harengus*)



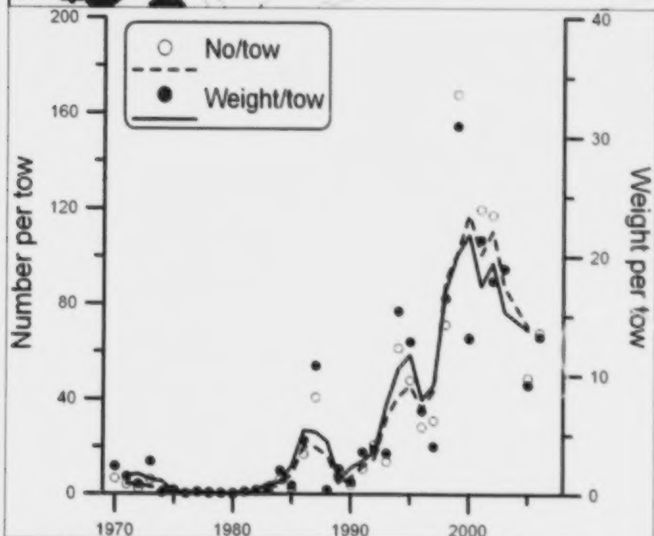
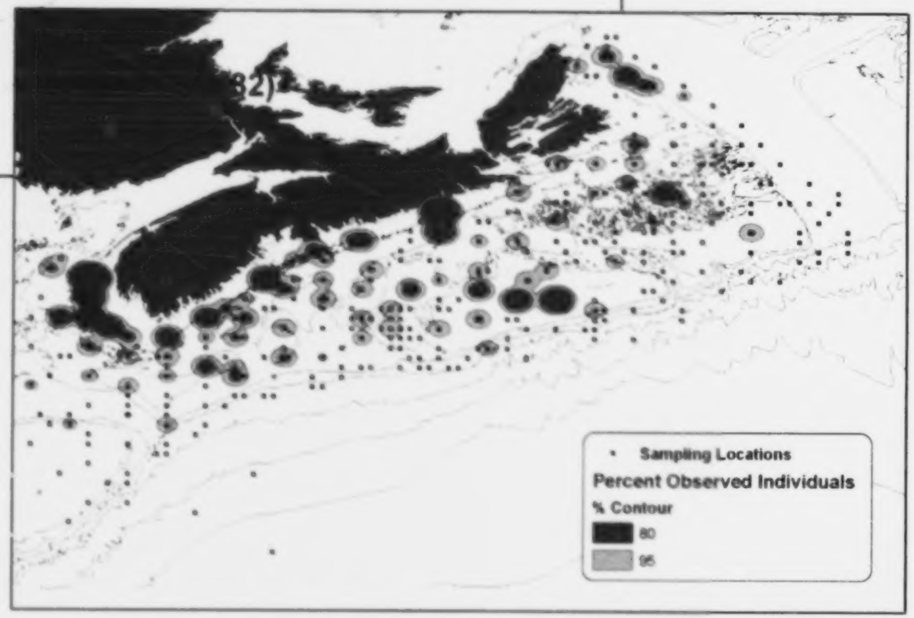
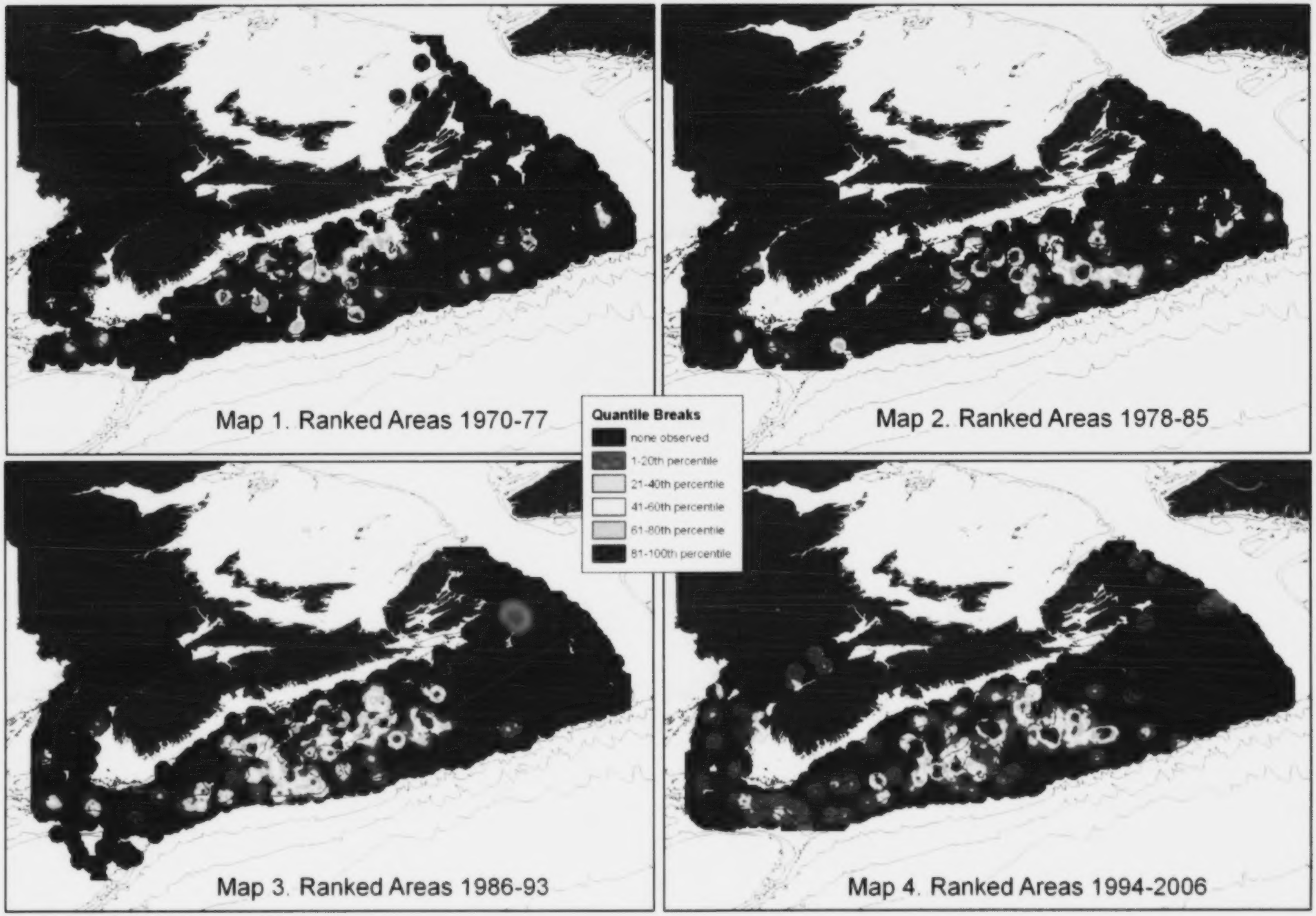


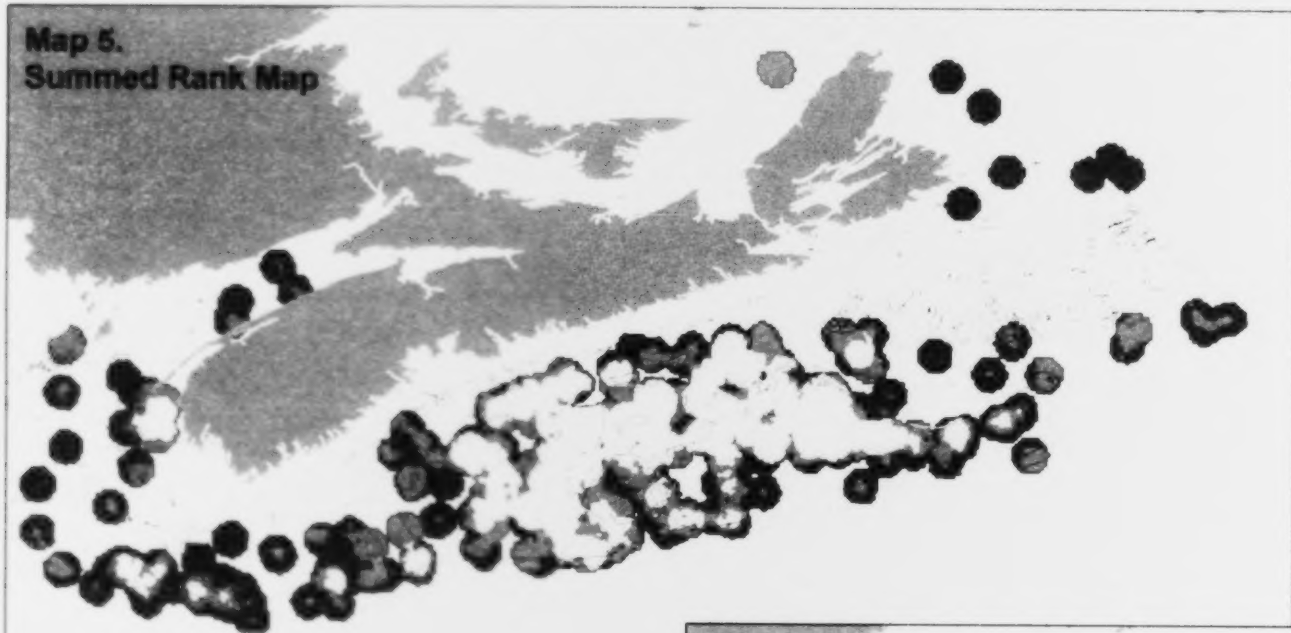
Figure 1. Population Trend

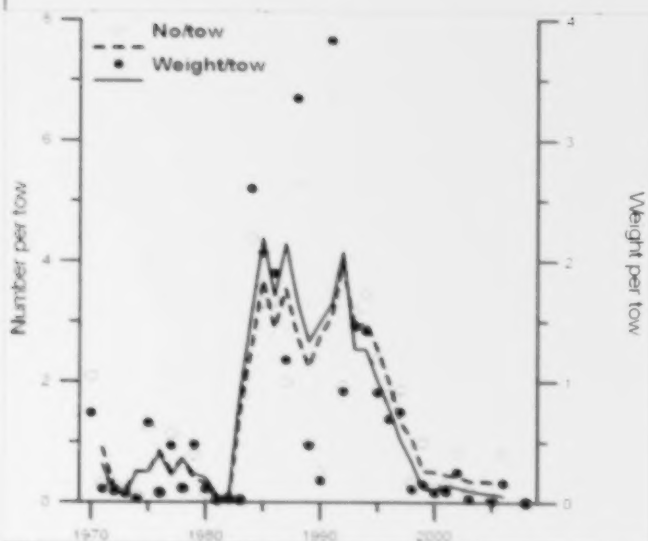




Mackerel (*Scomber scombrus*)

Mackerel
(*Scomber scombrus*)





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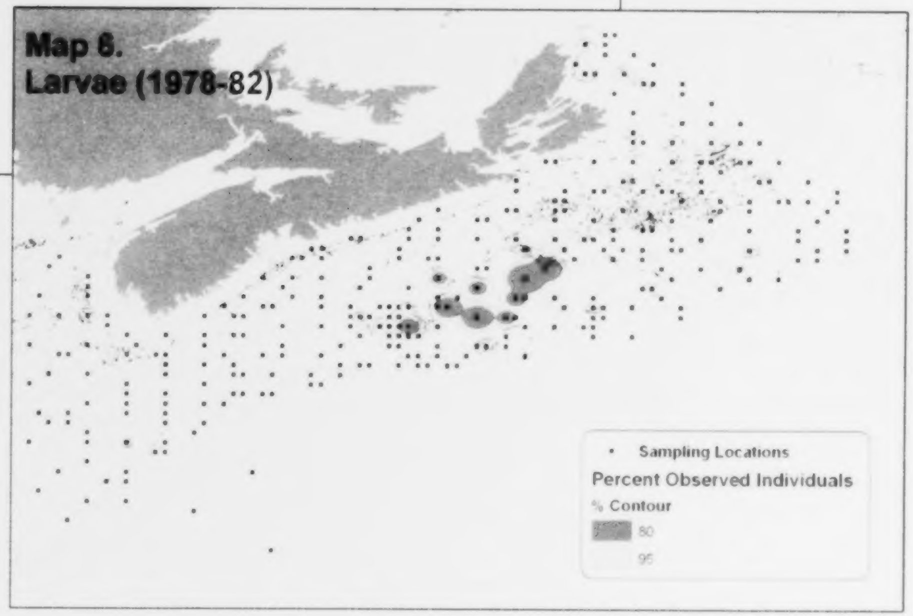
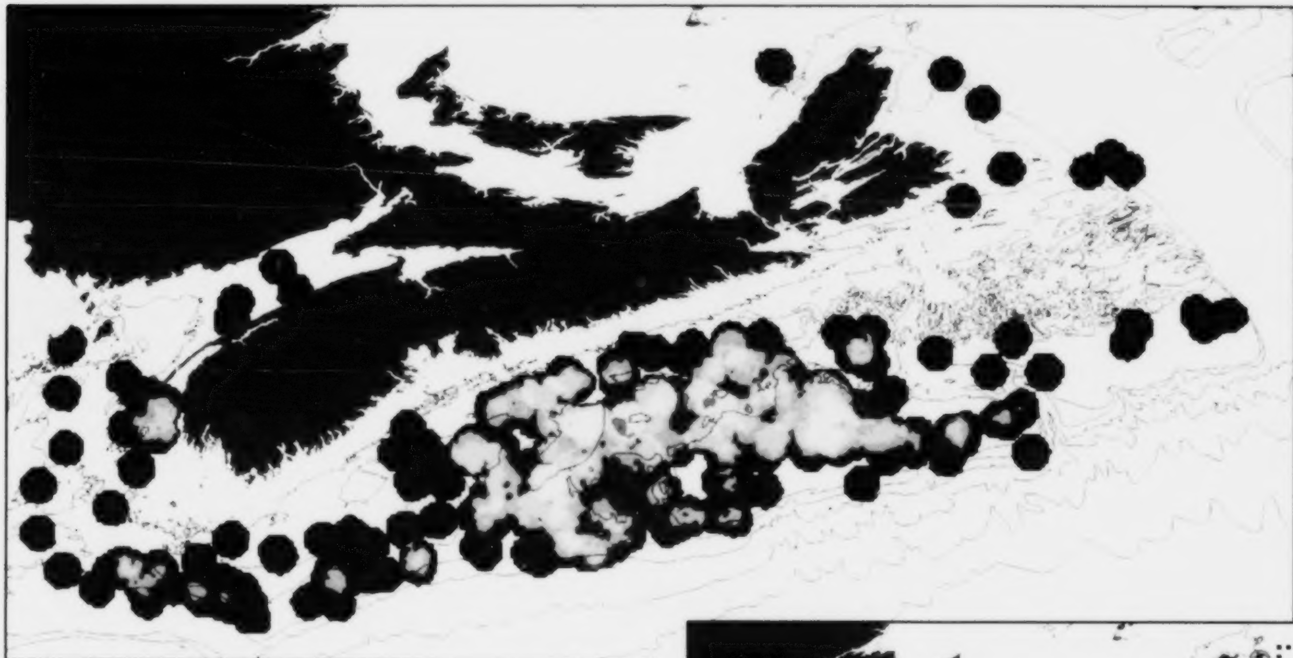
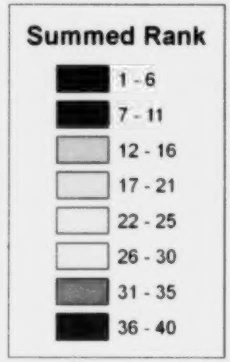


Mackerel
(*Scomber scombrus*)





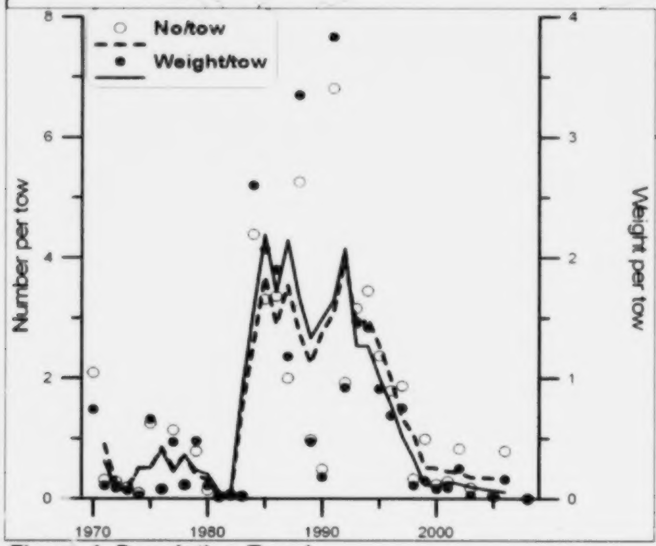
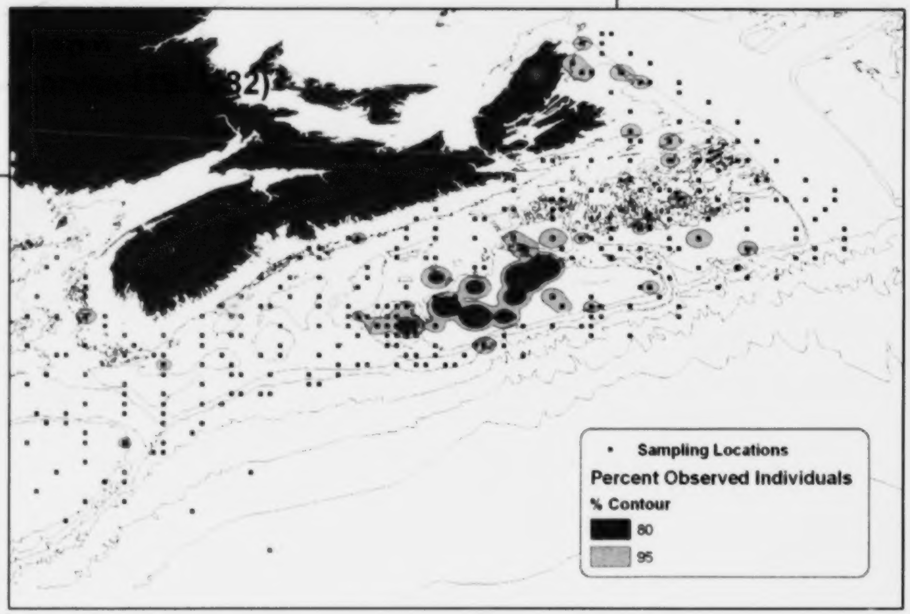
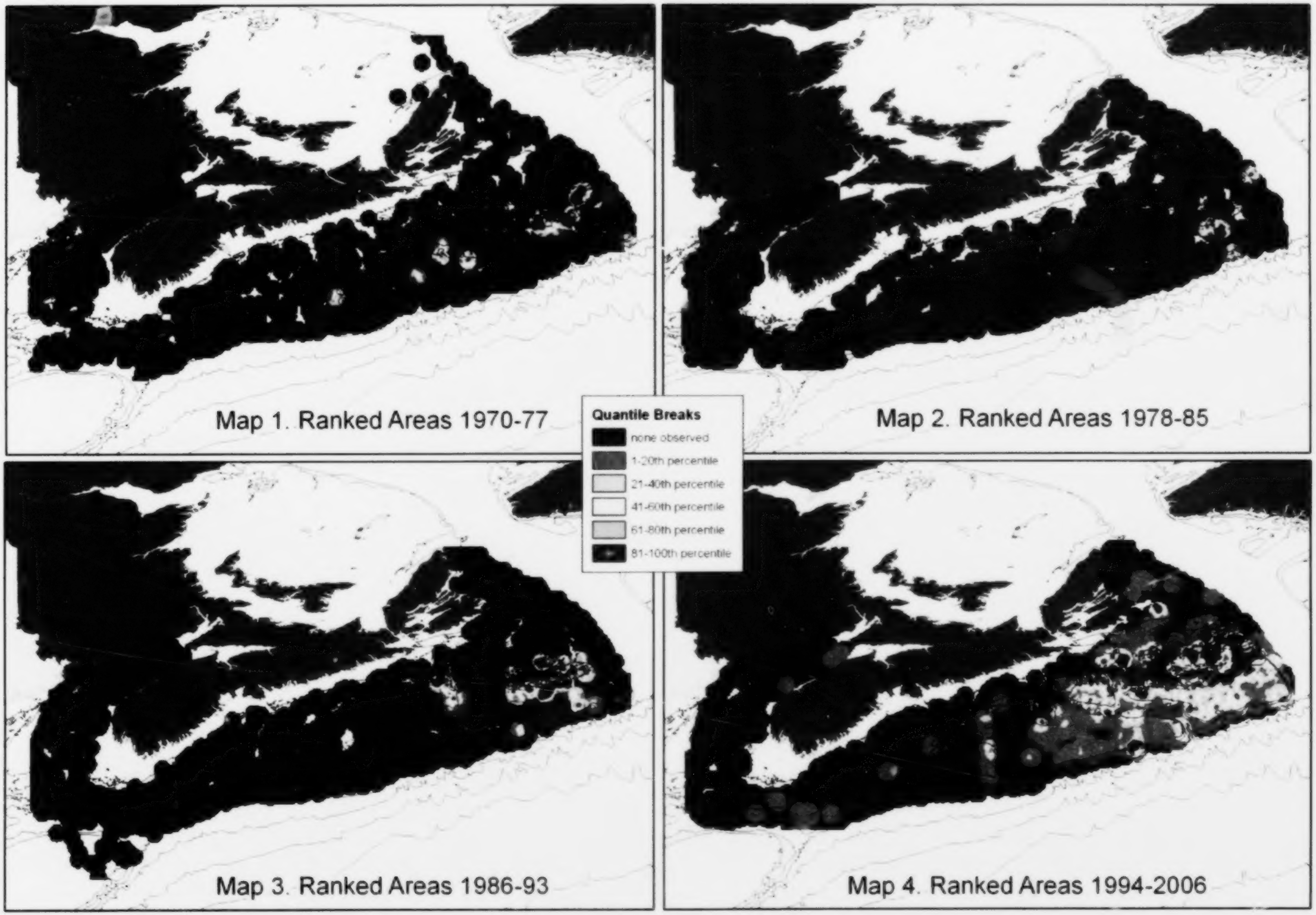


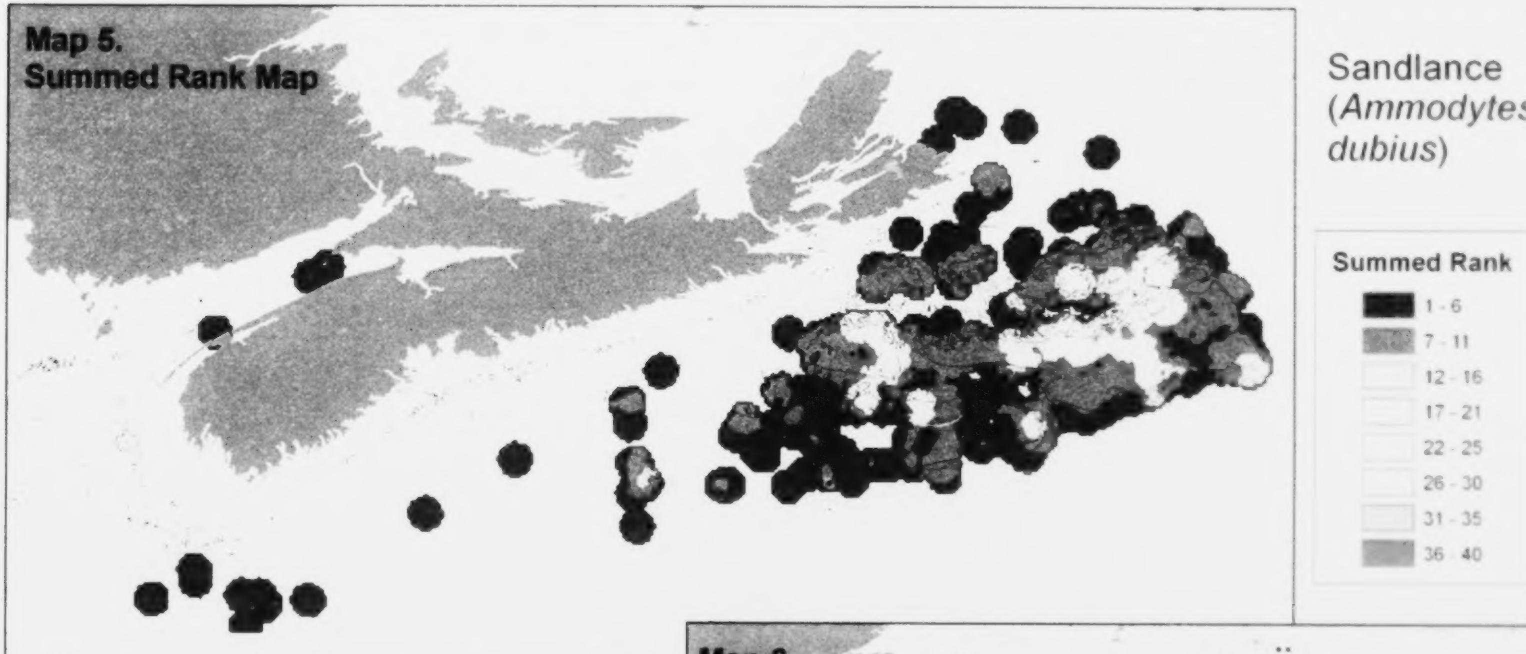
Figure 1. Population Trend





Sandlance(*Ammodytes dubius*)

Sandlance (*Ammodytes dubius*)



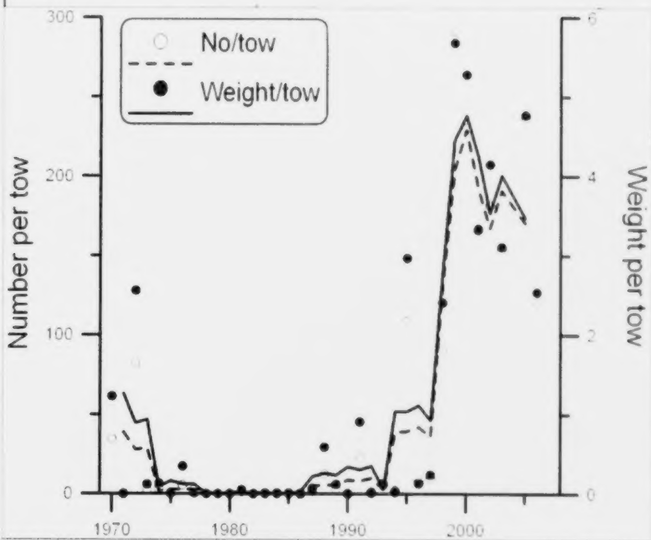
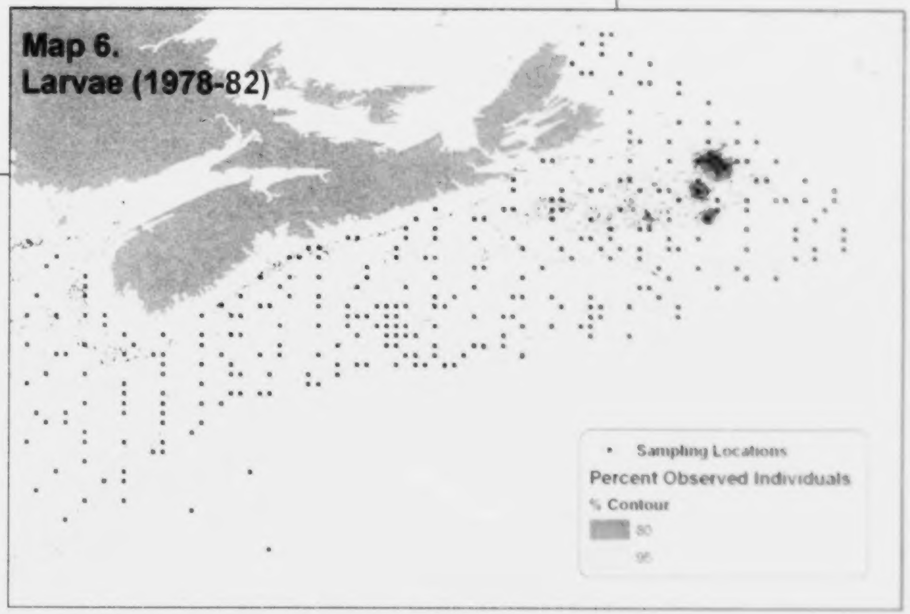


Figure 1. Population Trend



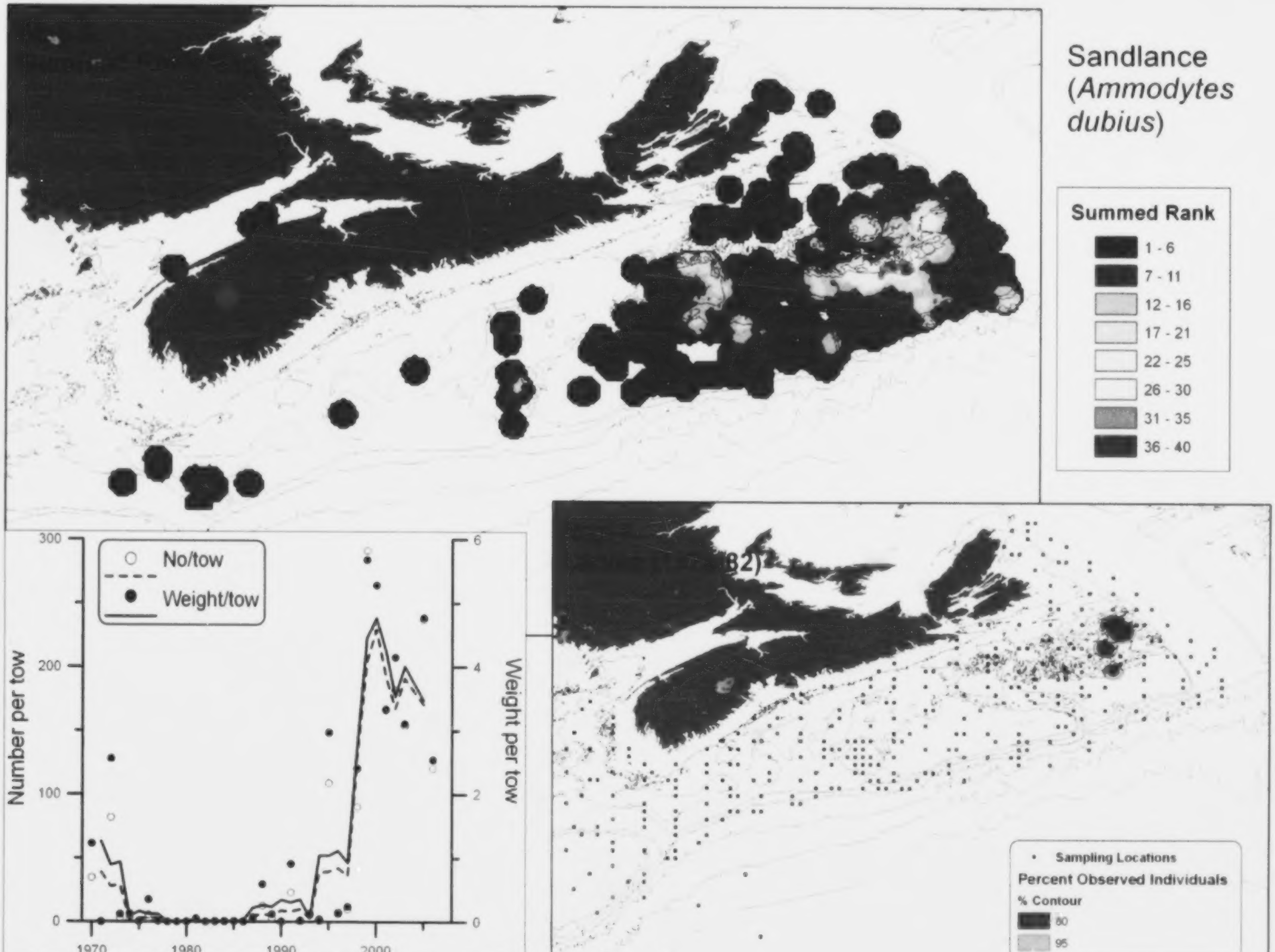
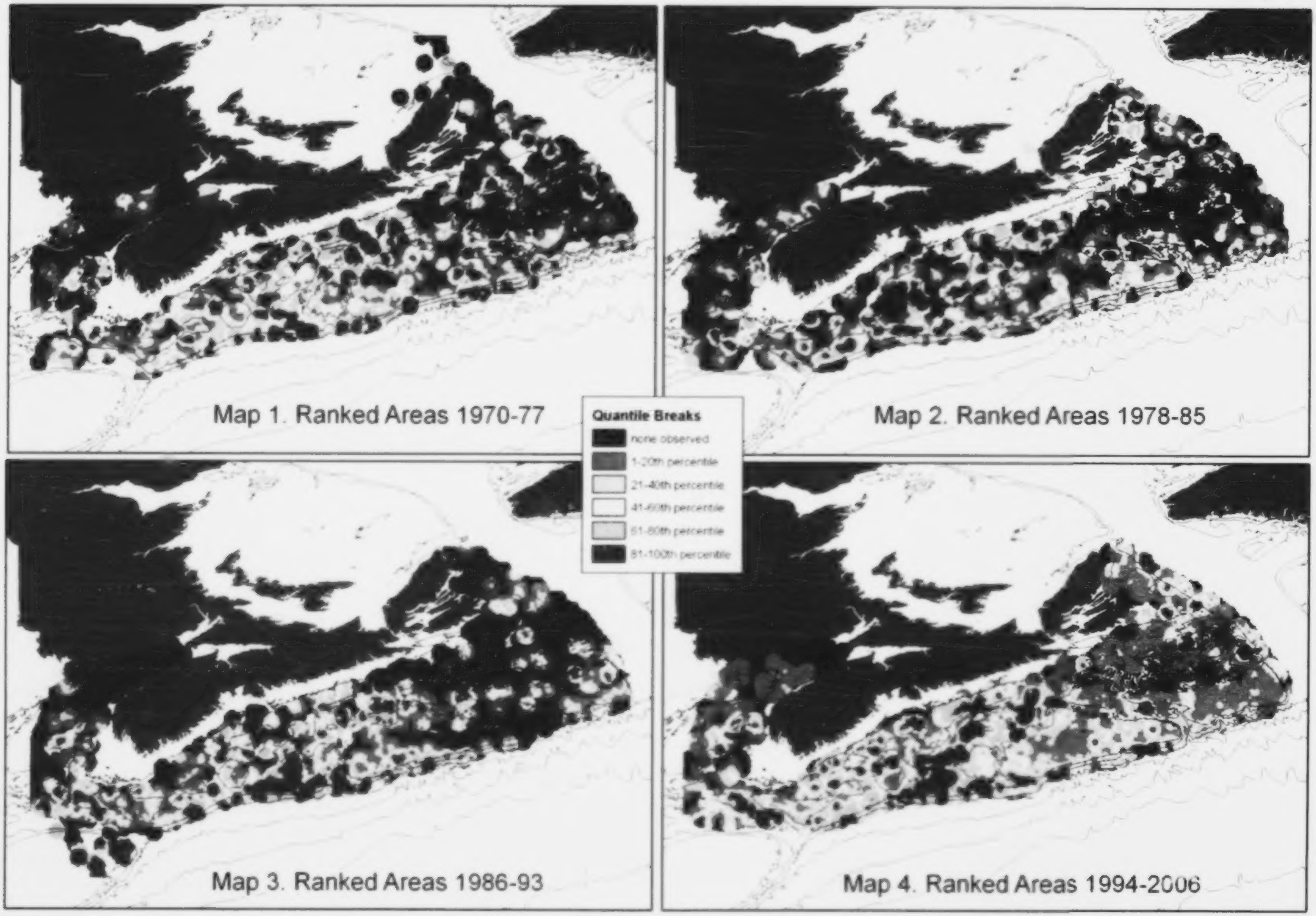
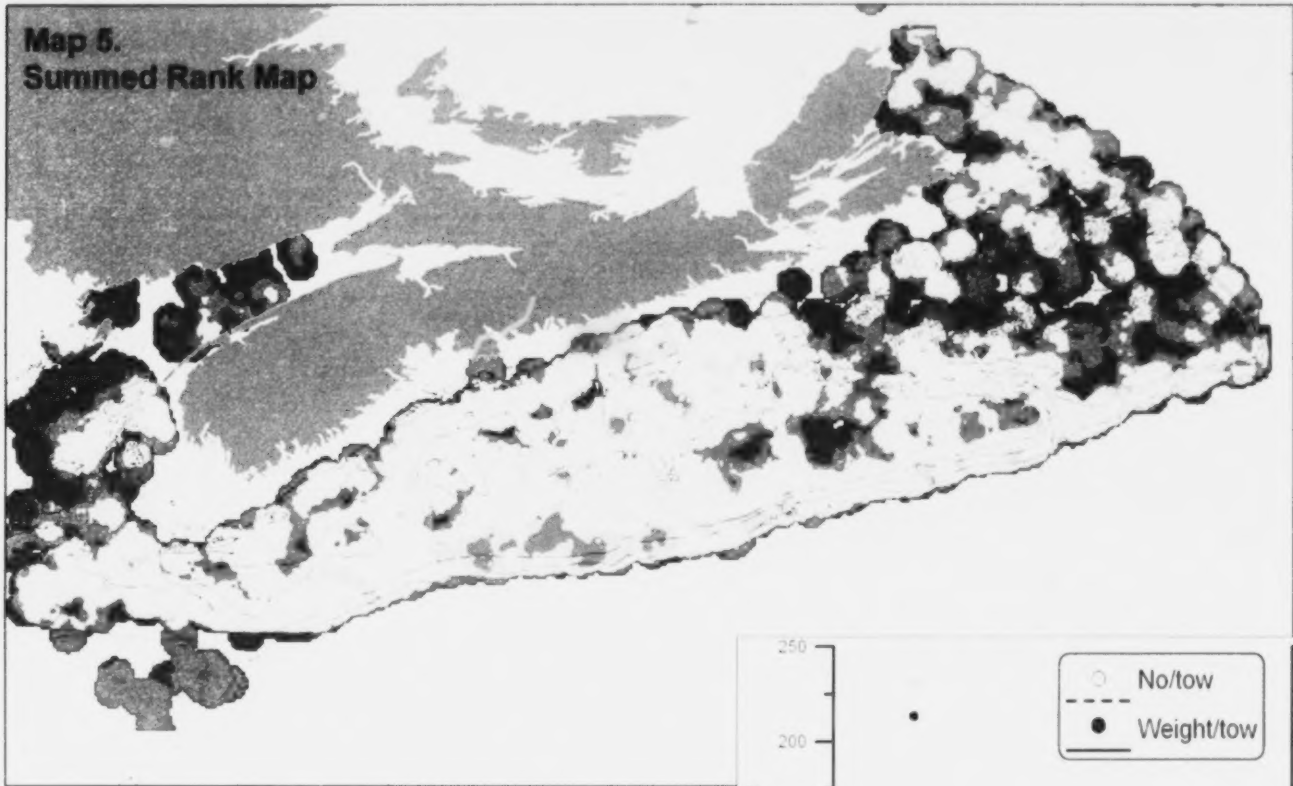


Figure 1. Population Trend



Northern Shortfin Squid (*Illex illecebrosus*)



Northern Shortfin Squid (*Illex illecebrosus*)

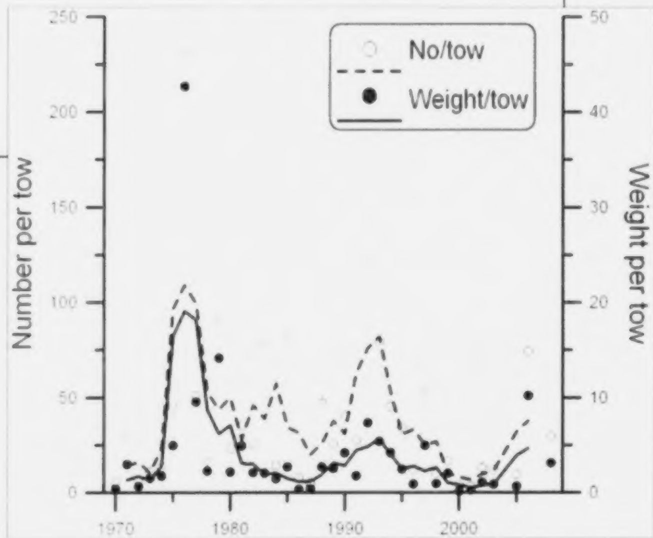
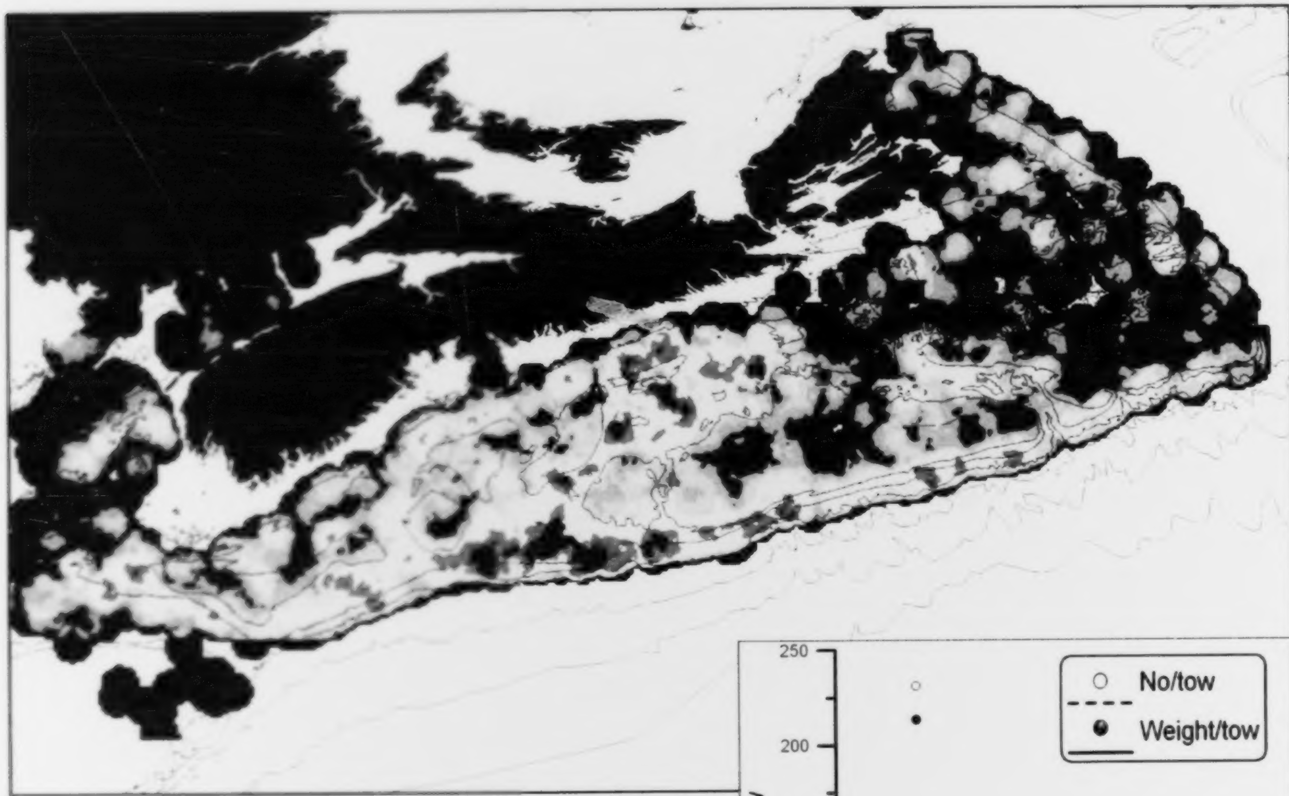
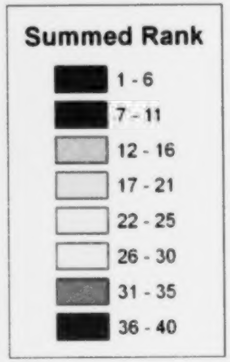


Figure 1. Population Trend

Northern Shortfin Squid (*Illex illecebrosus*)





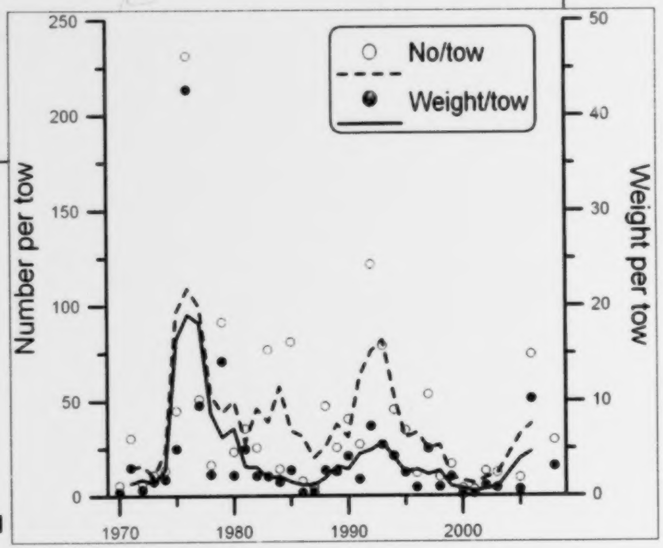
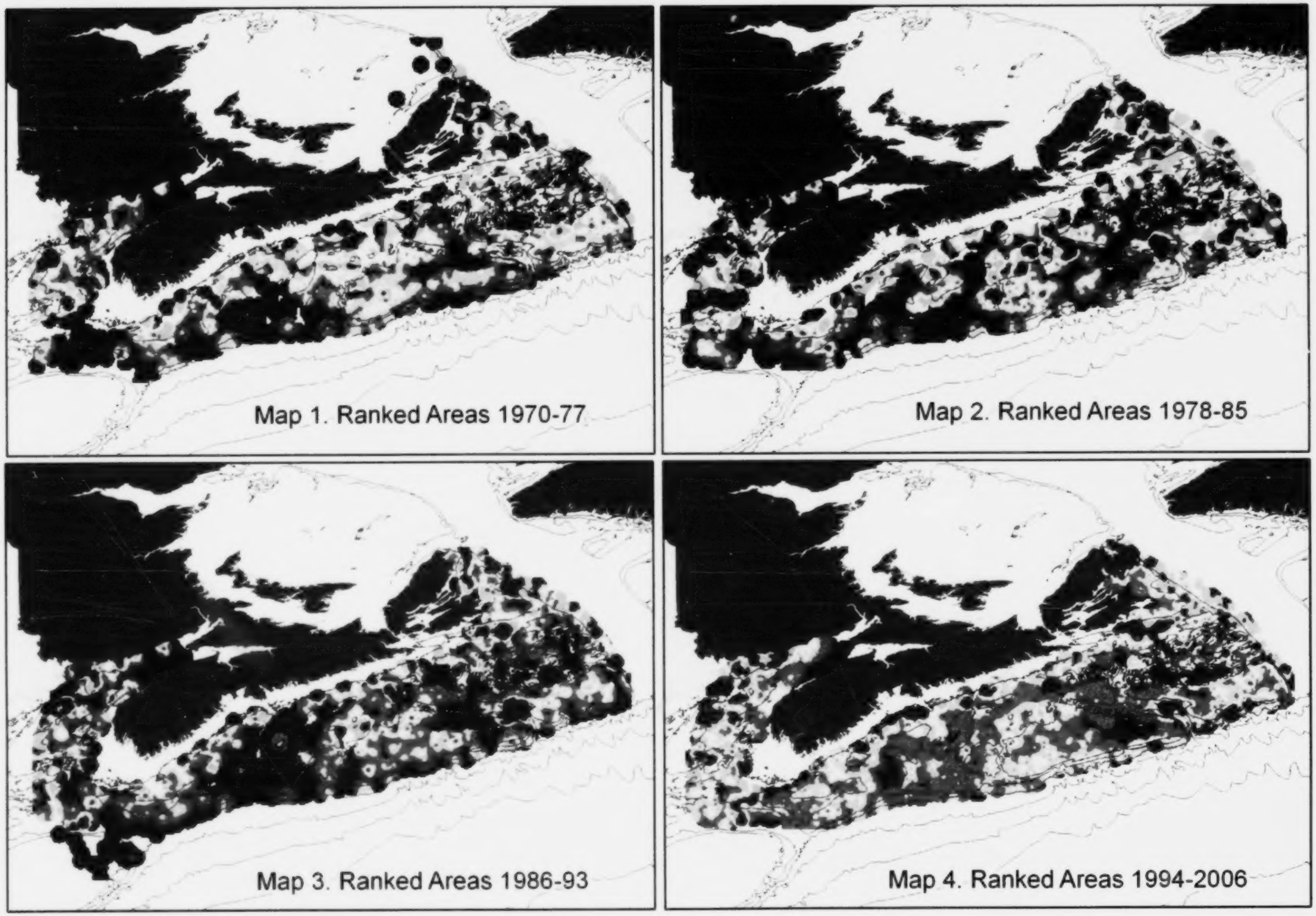
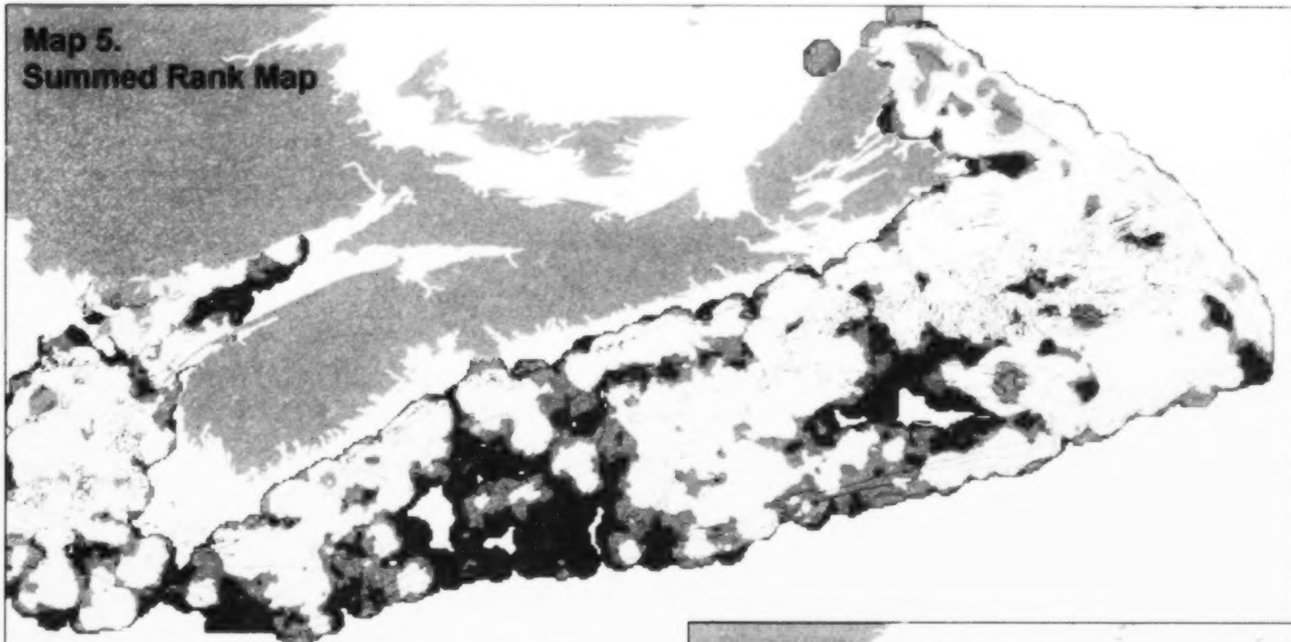


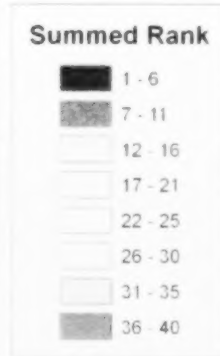
Figure 1. Population Trend



Witch Flounder (*Glyptocephalus cynoglossus*)



Witch Flounder (*Glyptocephalus cynoglossus*)



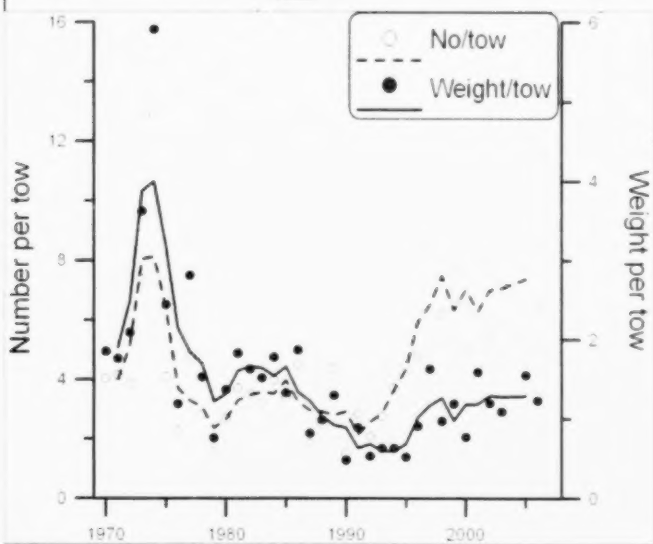
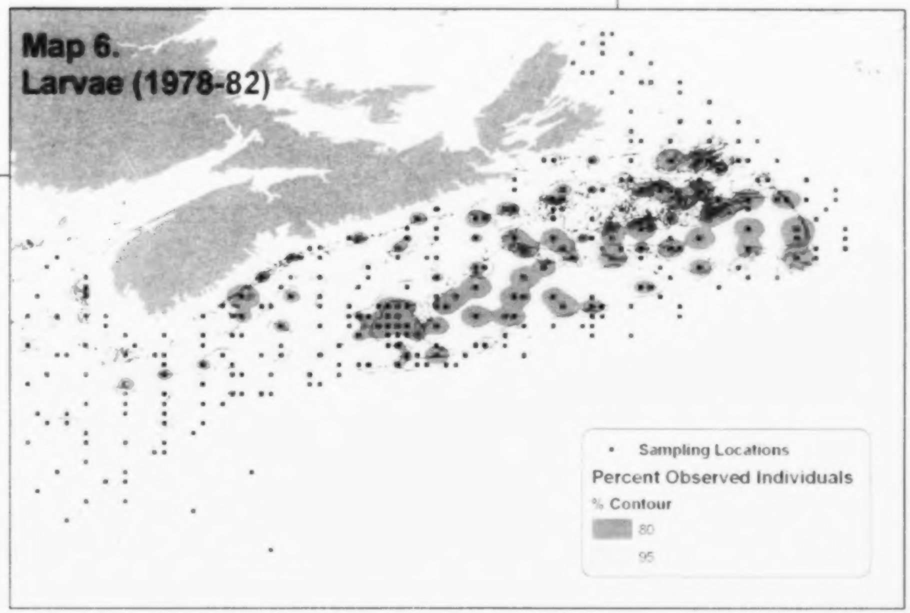
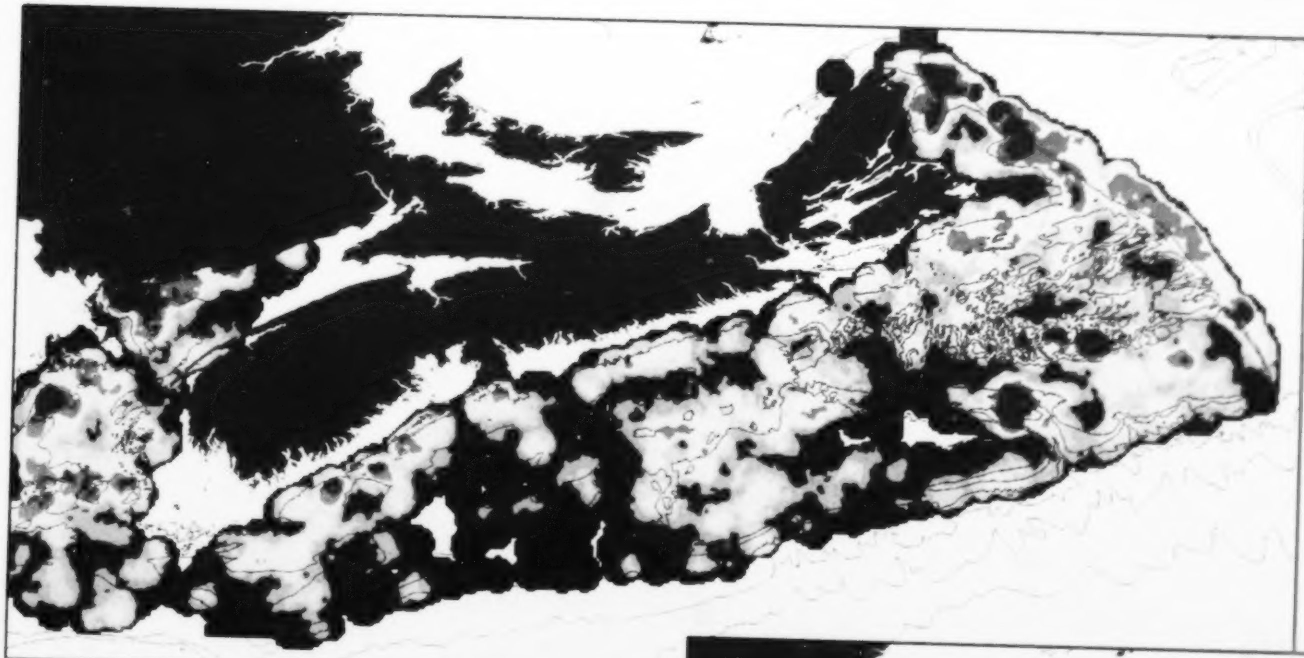
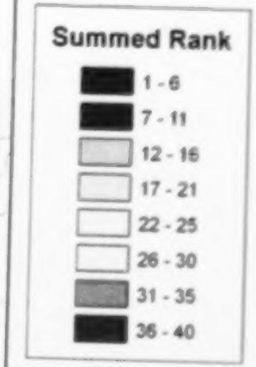


Figure 1. Population Trend





Witch Flounder
(*Glyptocephalus cynoglossus*)



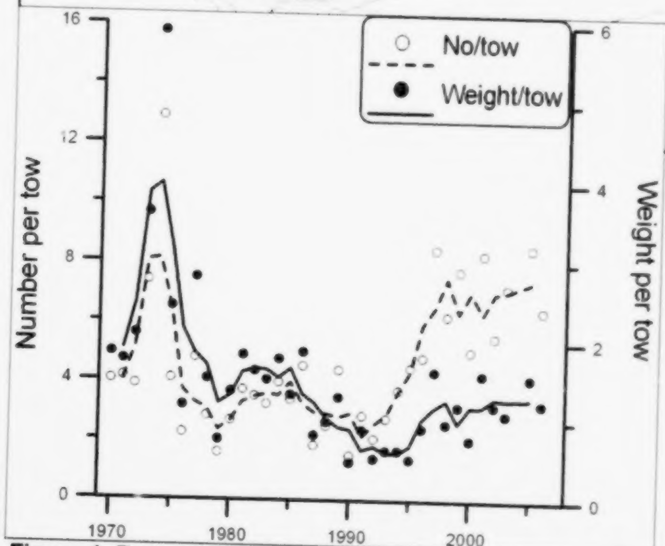
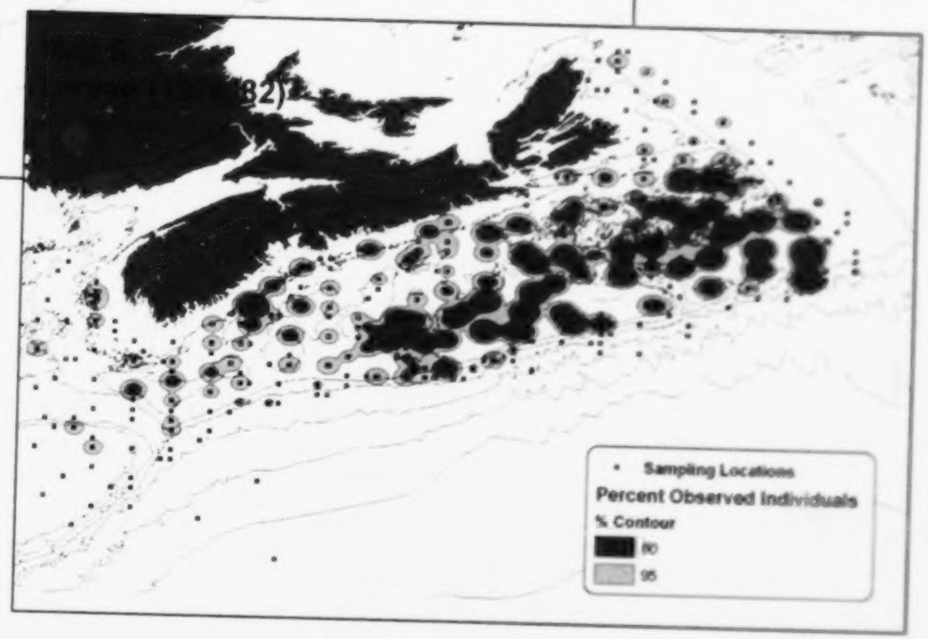


Figure 1. Population Trend



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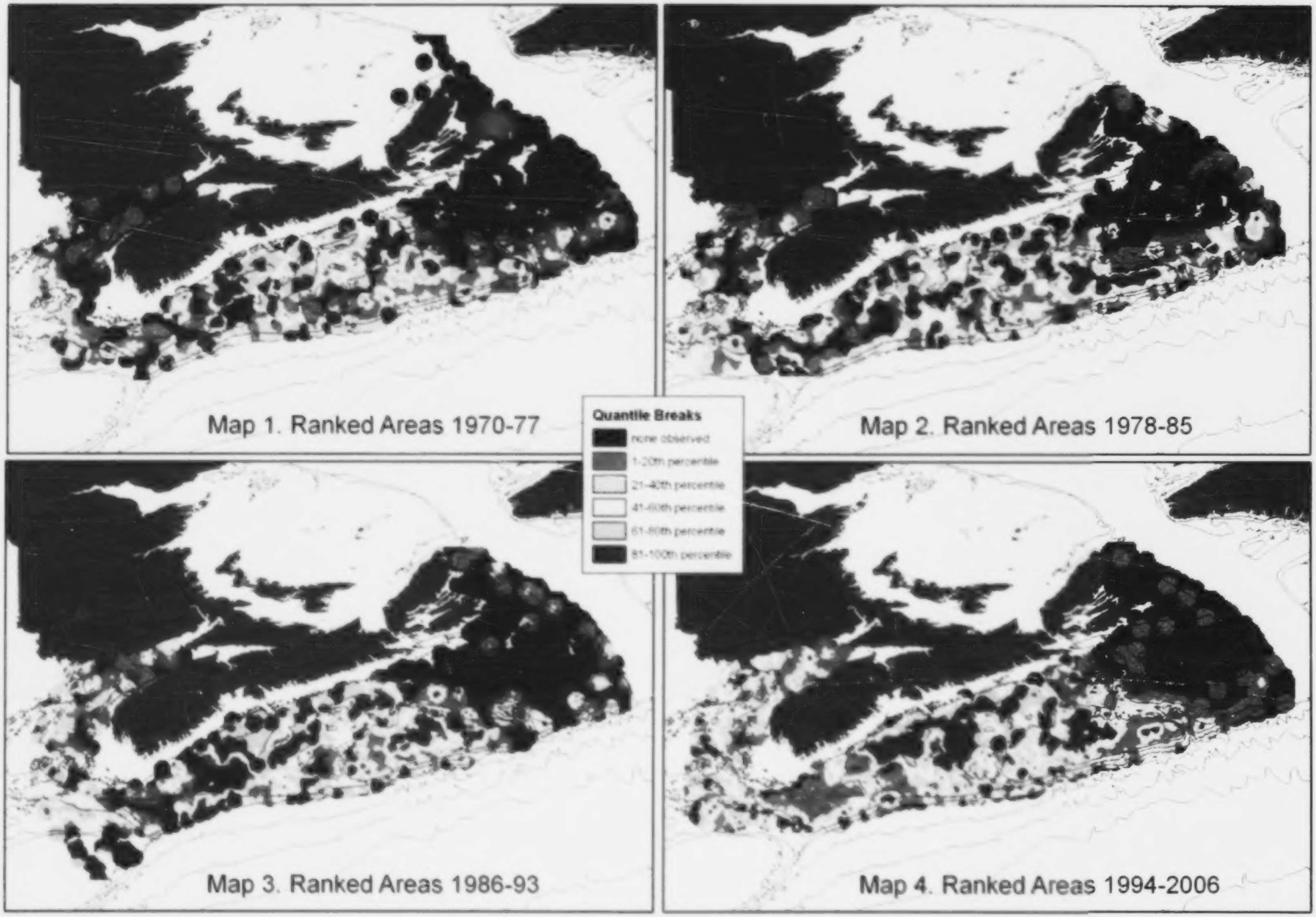
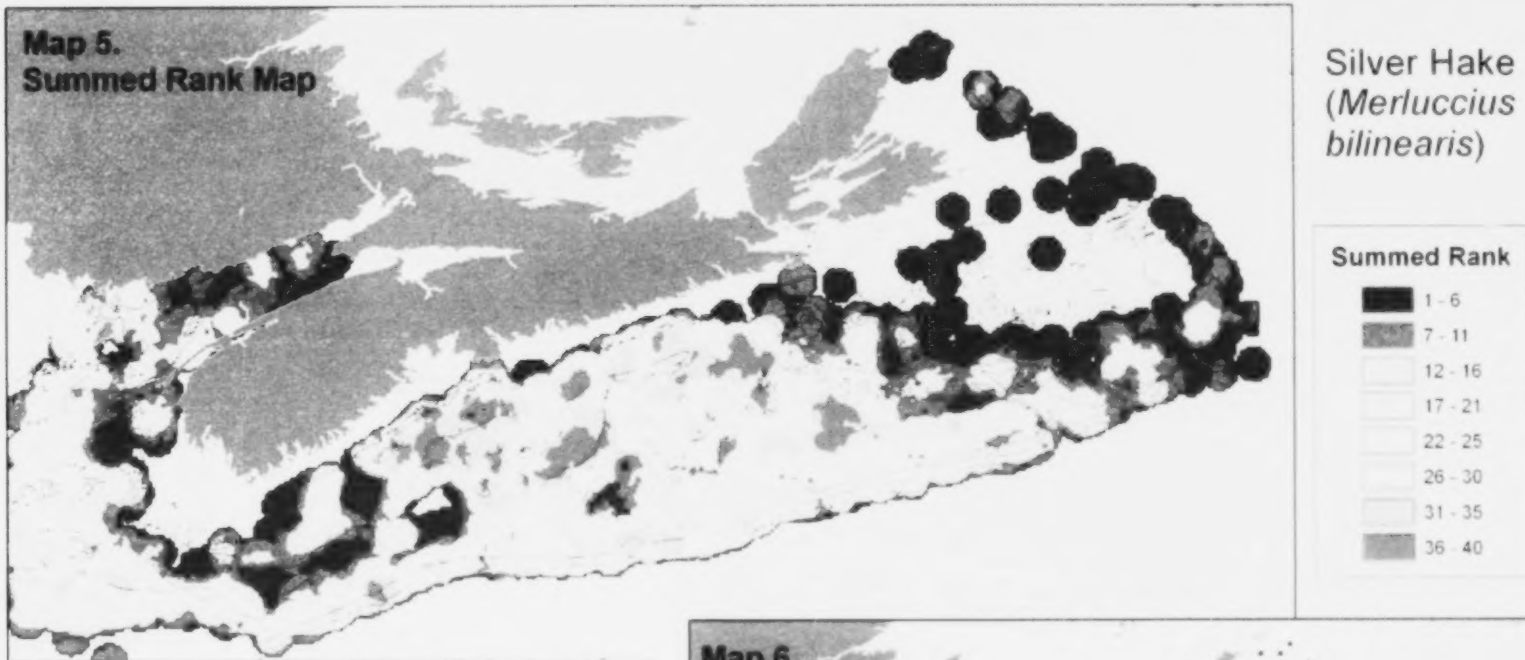
3.2 Influential Predators

The results of our evaluation of areas of persistently high ranking biomass and population trends can be found on the following pages for the these species identified as influential predators for the Scotian Shelf: Silver Hake (*Merluccius bilinearis*); American Plaice (*Hippoglossoides platessoides*); Atlantic Cod (*Gadus morhua*); Haddock (*Melanogrammus aeglefinus*); Atlantic Halibut (*Hippoglossus hippoglossus*); Longhorn Sculpin (*Myoxocephalus octodecemspinosus*); Pollock (*Pollachius virens*); Red Hake (*Urophycis chuss*); Redfish (*Sebastes* spp.); Smooth Skate (*Malacoraja senta*); Spiny Dogfish (*Squalus acanthias*); White Hake (*Urophycis tenuis*); Winter Skate (*Leucoraja ocellata*).



Silver Hake (*Merluccius bilinearis*)

Silver Hake (*Merluccius bilinearis*)



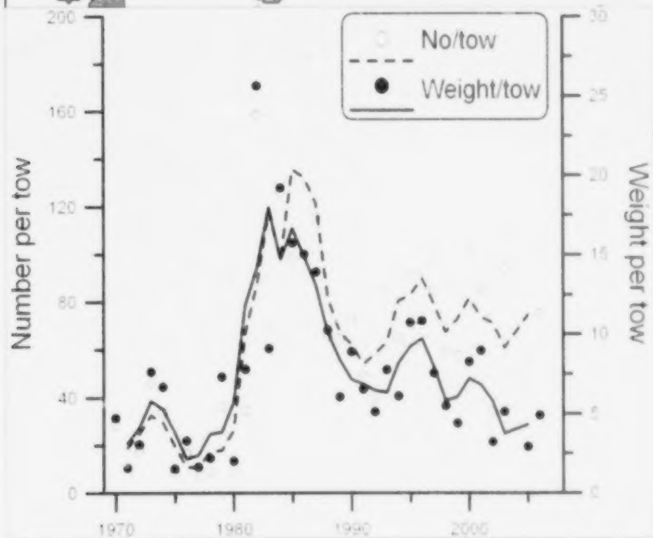
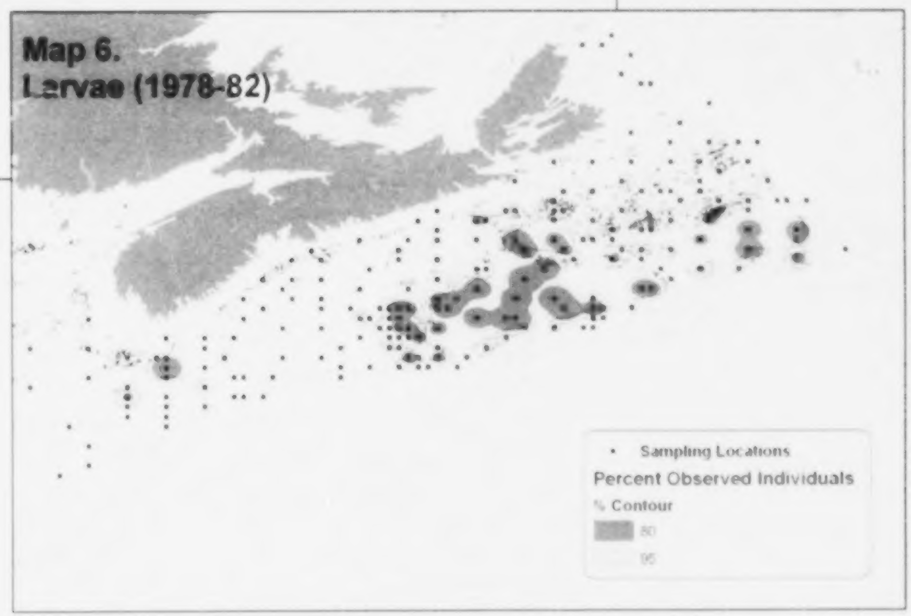
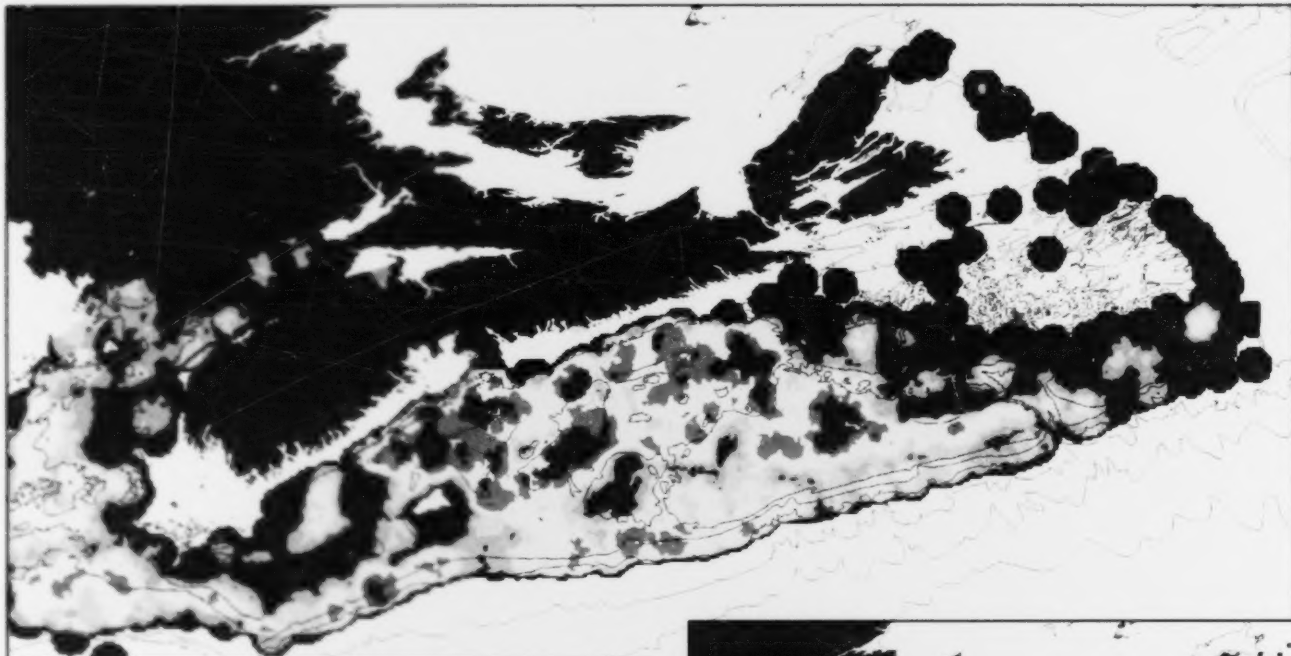


Figure 1. Population Trend



Silver Hake (*Merluccius bilinearis*)



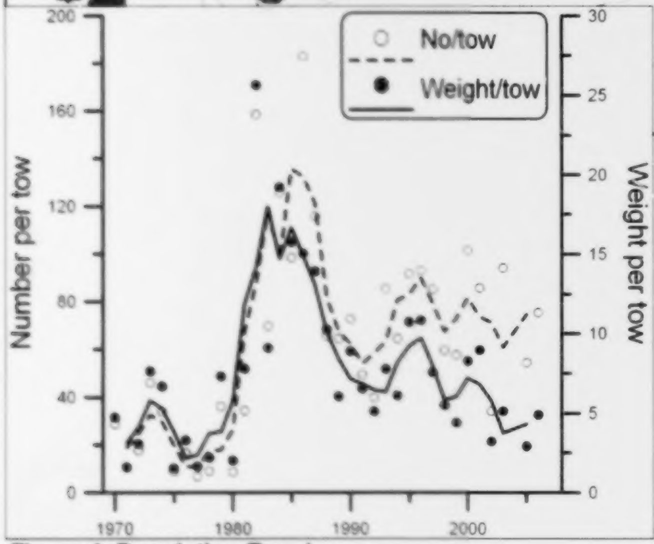
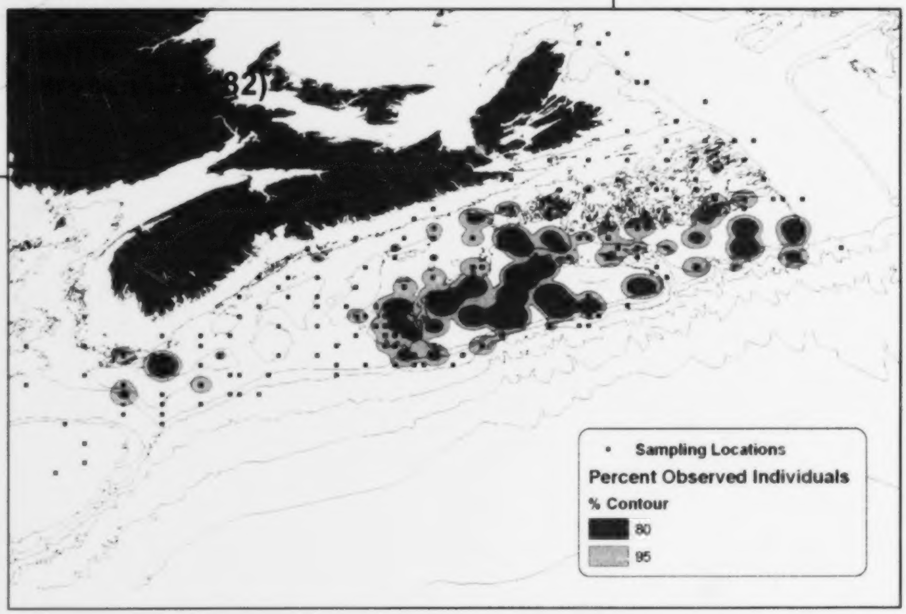
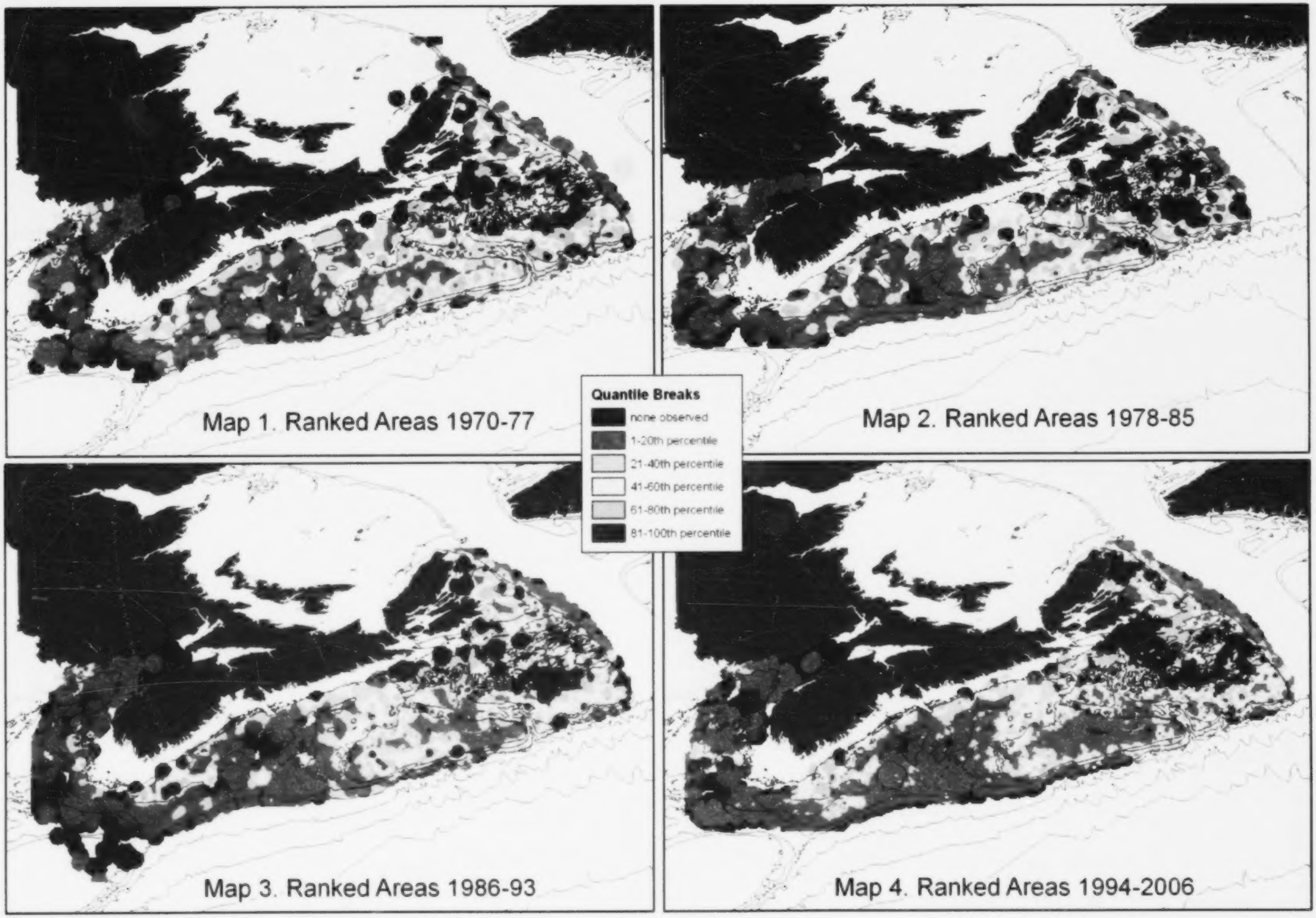


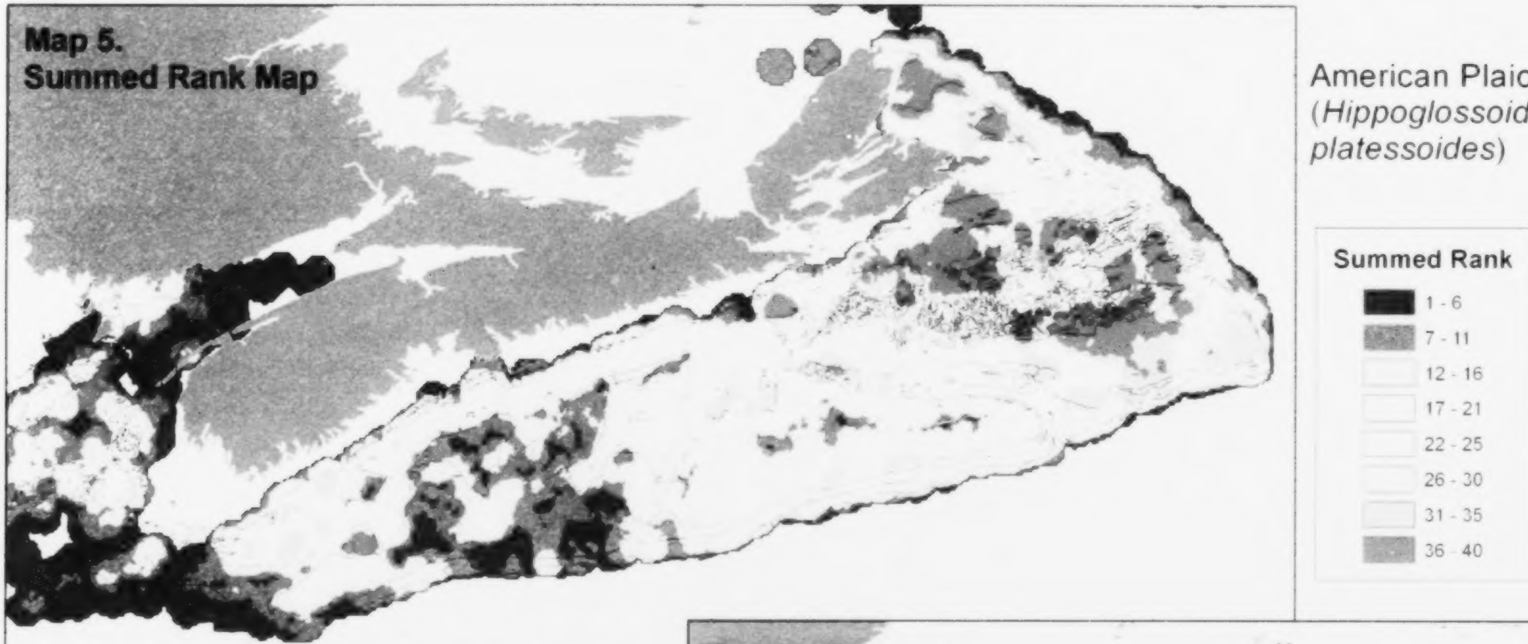
Figure 1. Population Trend



American Plaice (*Hippoglossoides platessoides*)



American Plaice
(*Hippoglossoides platessoides*)



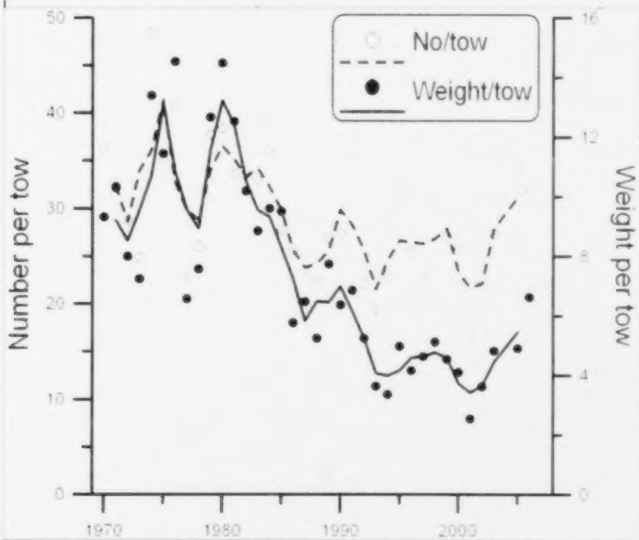
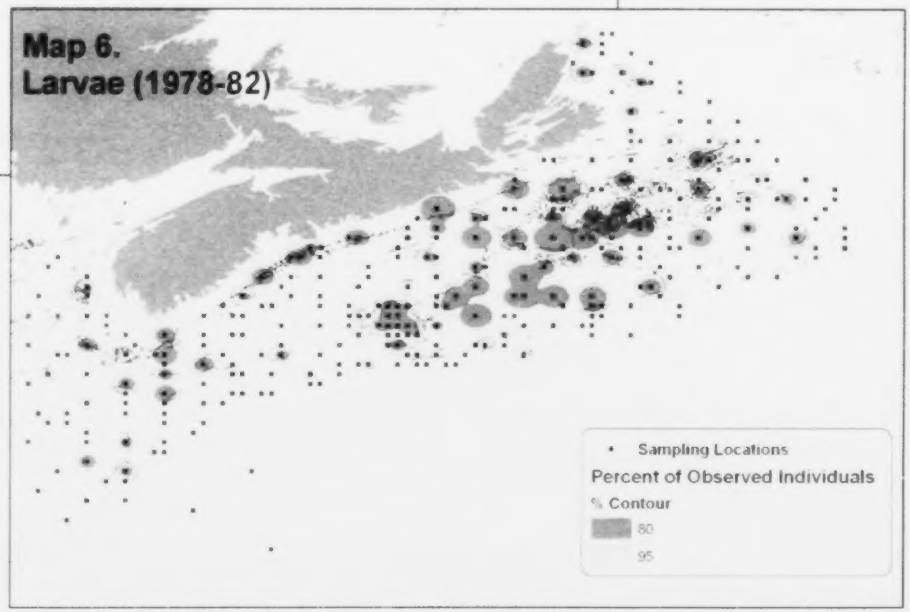
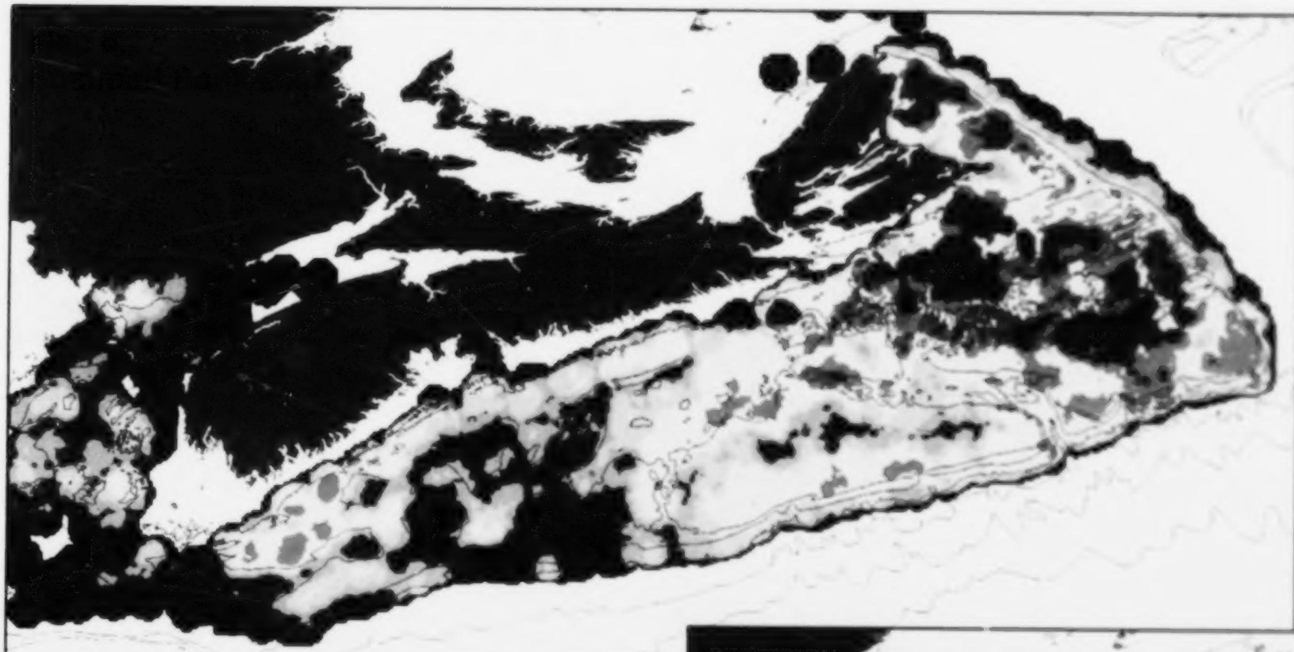
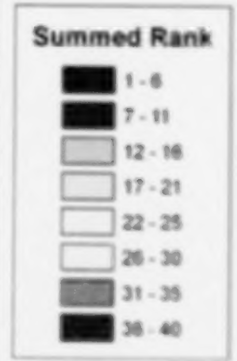


Figure 1. Population Trend



American Plaice
(*Hippoglossoides platessoides*)





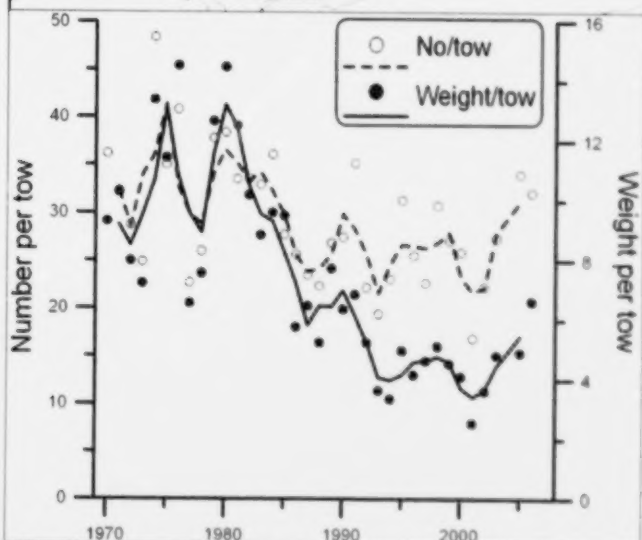
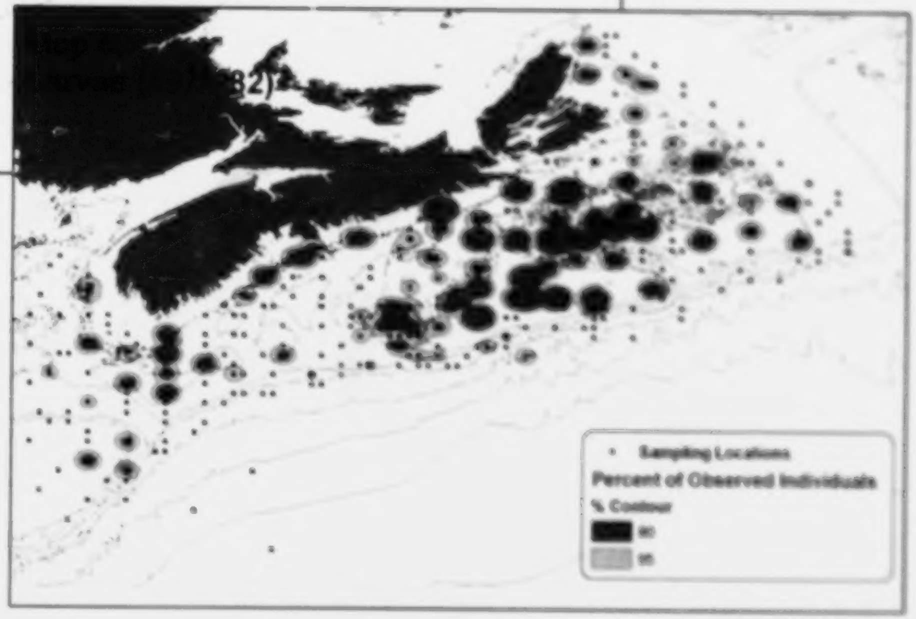
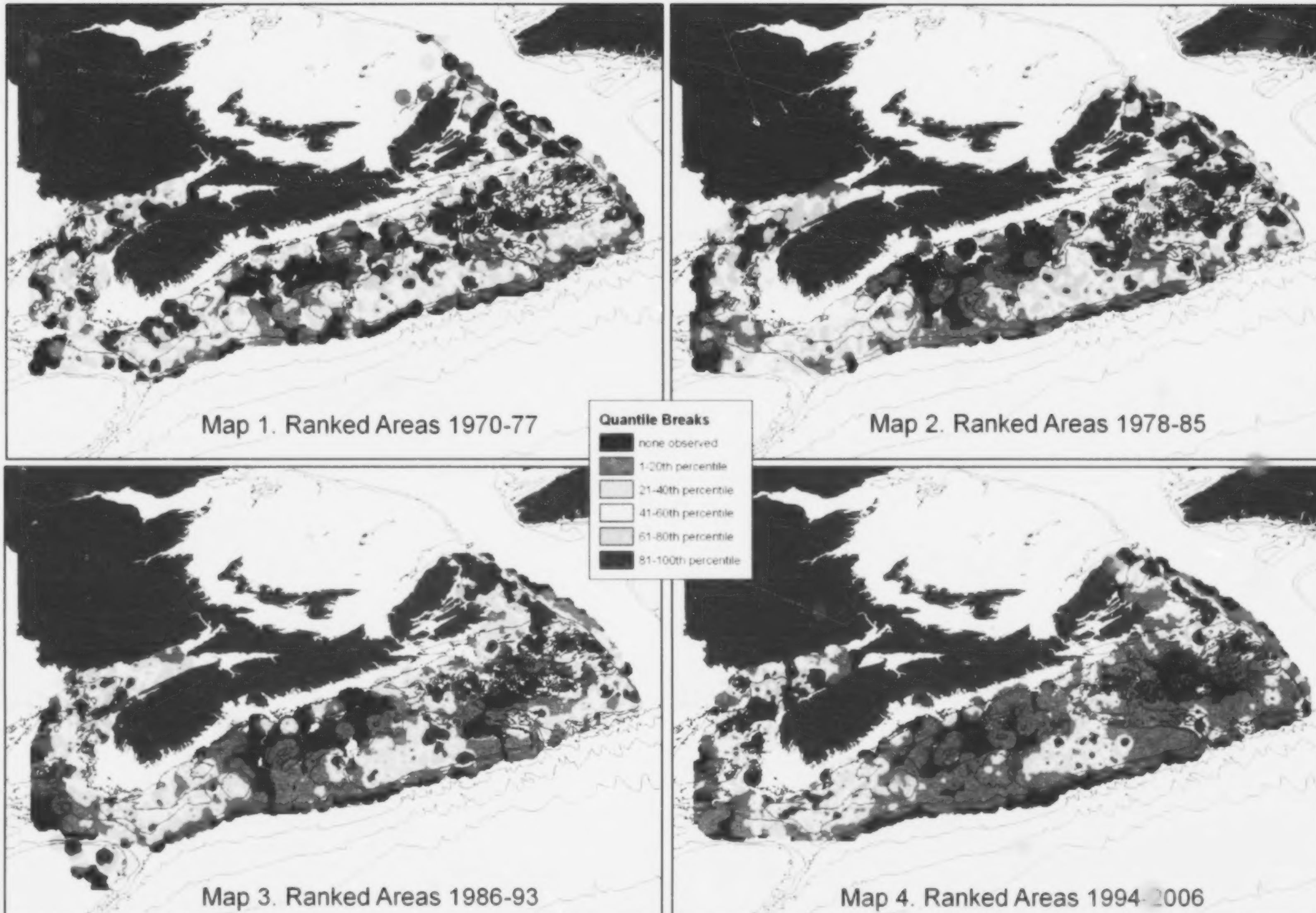


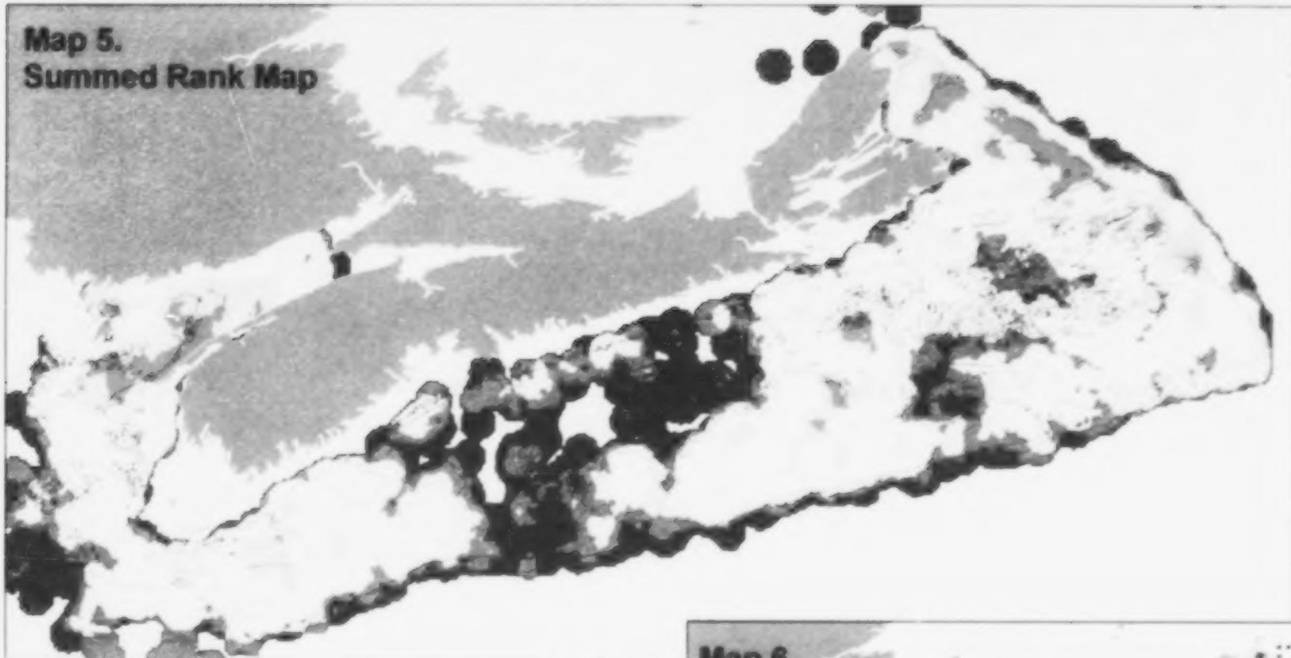
Figure 1. Population Trend

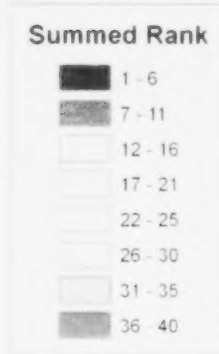




Atlantic Cod (*Gadus morhua*)

Atlantic Cod (*Gadus morhua*)





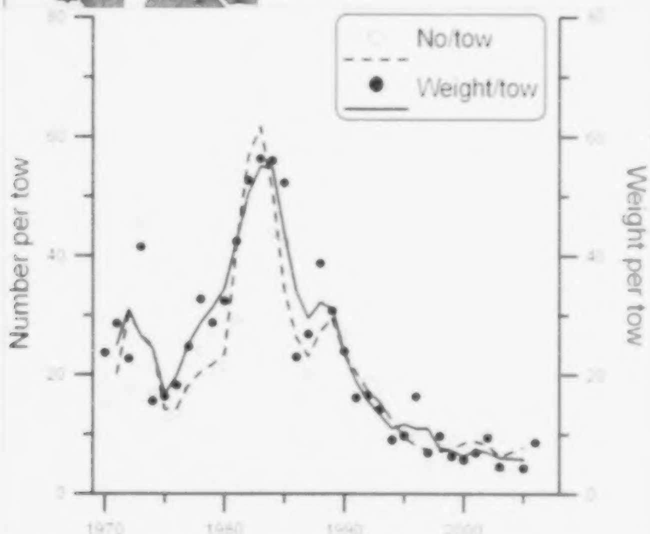
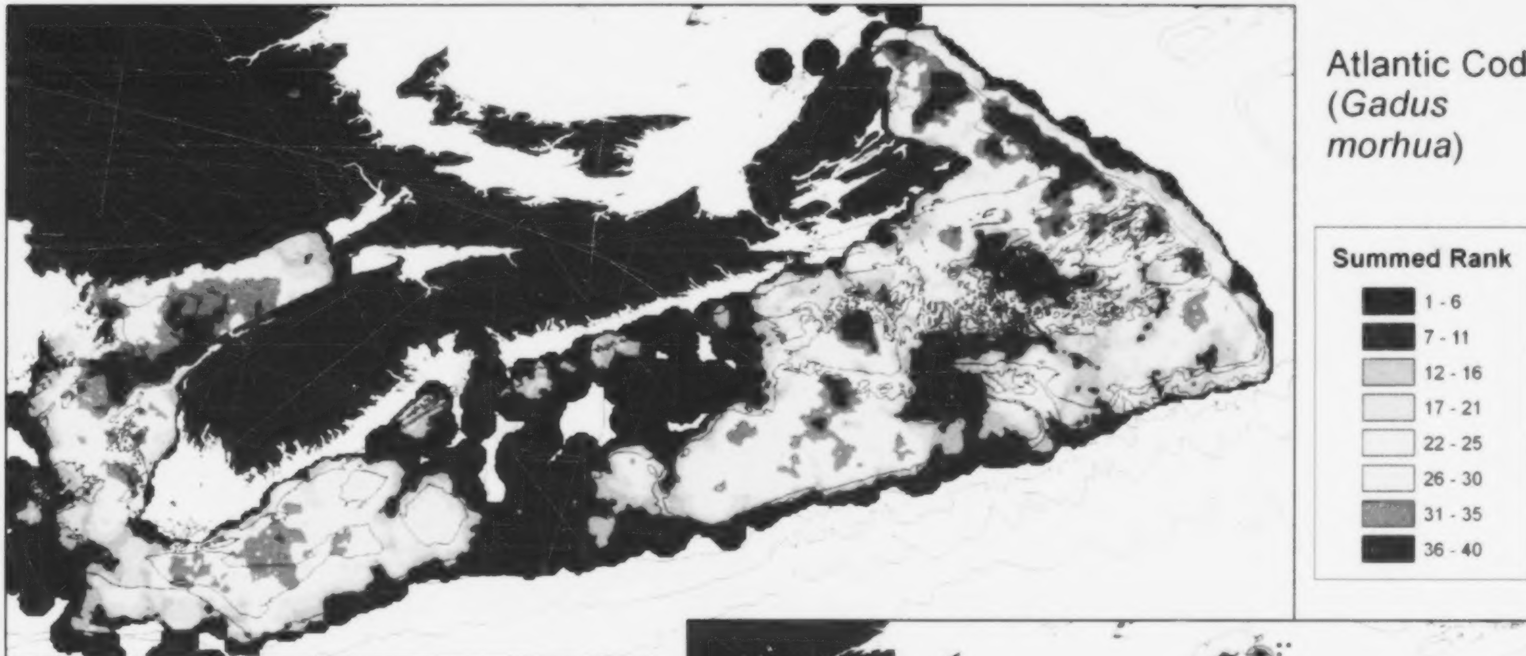


Figure 1. Population Trend

Atlantic Cod (*Gadus morhua*)



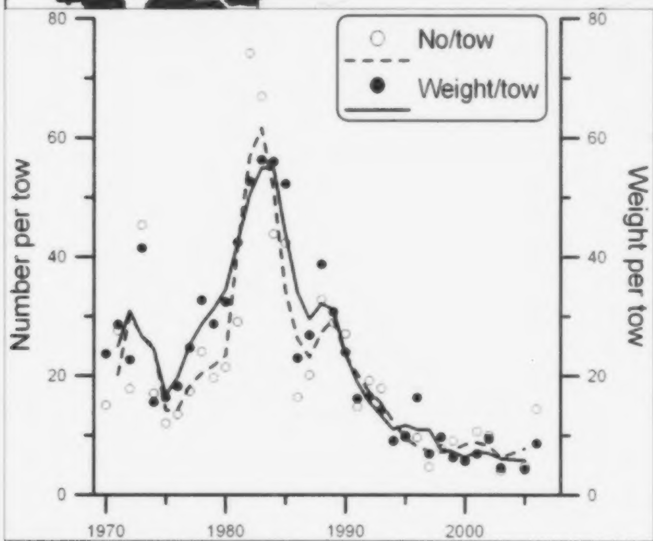
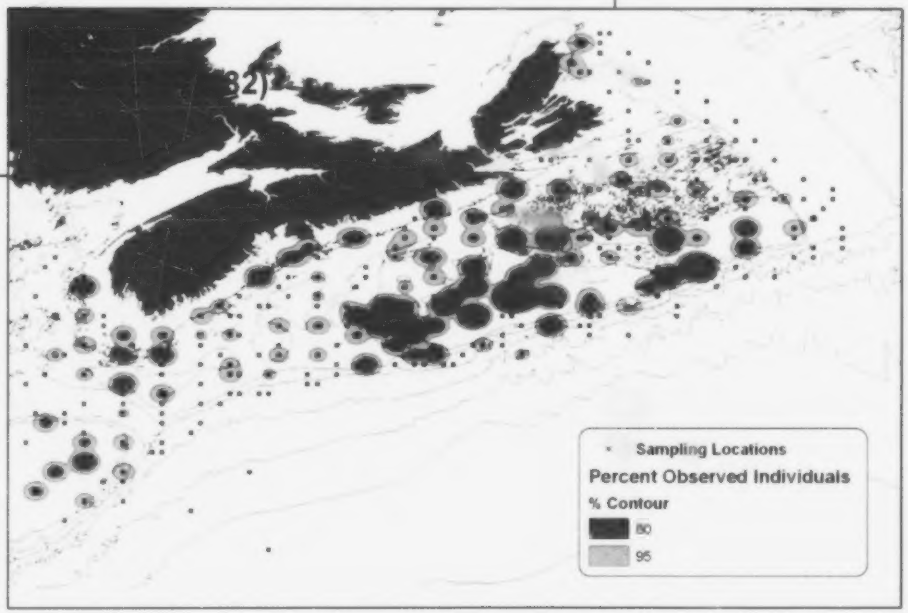
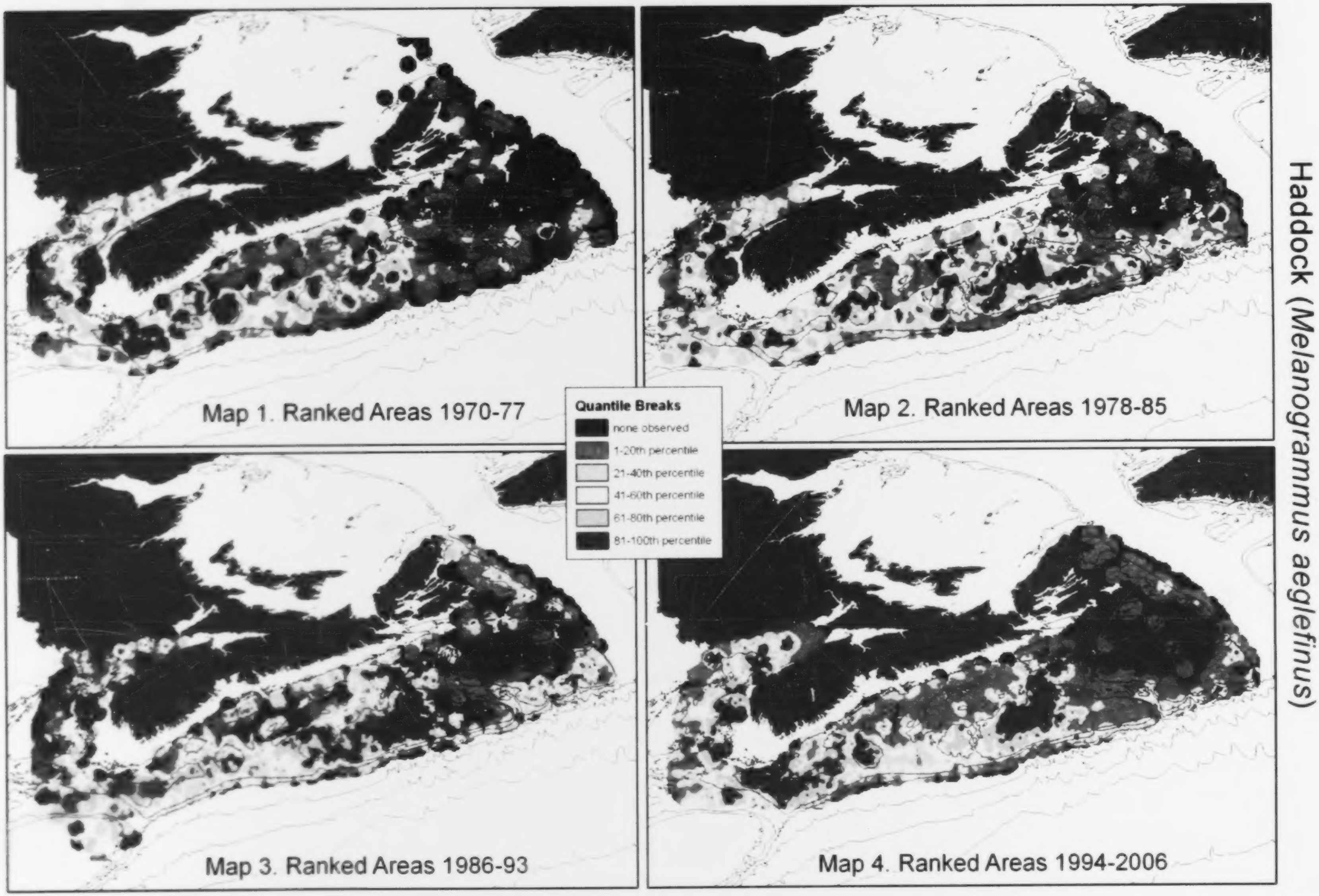
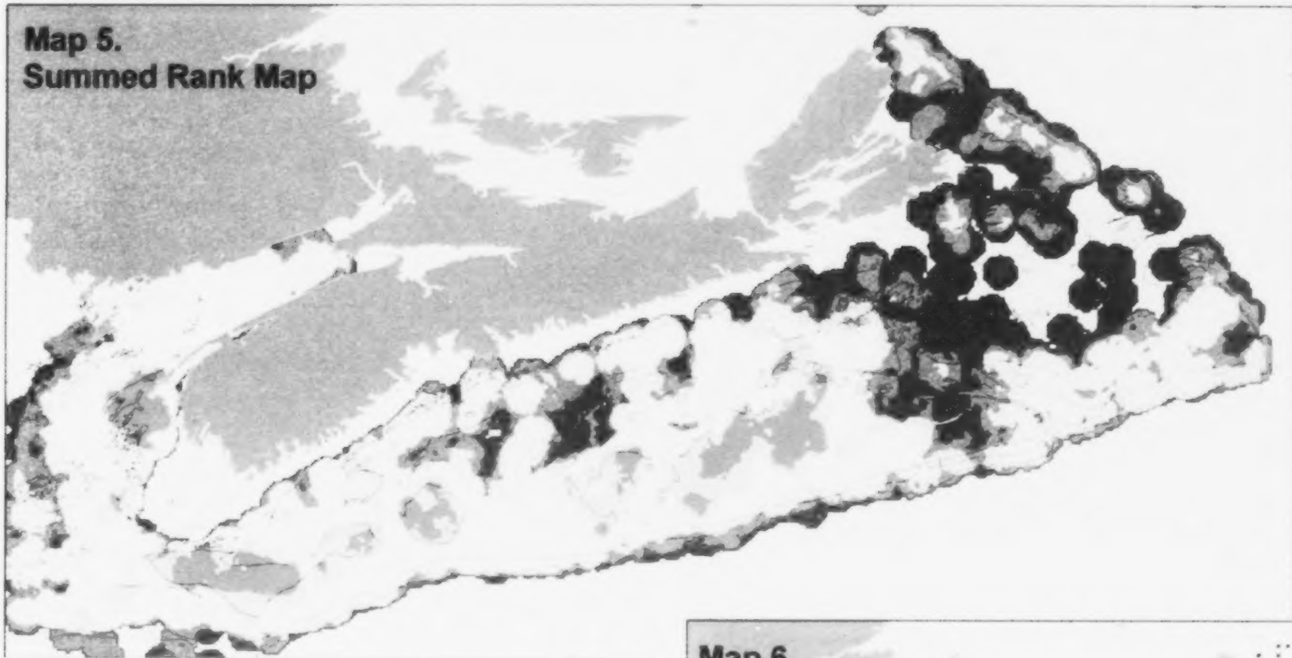


Figure 1. Population Trend




Map 1. Ranked Areas 1970-77
Map 2. Ranked Areas 1978-85
Map 3. Ranked Areas 1986-93
Map 4. Ranked Areas 1994-2006
Quantile Breaks
none observed
1-20th percentile
21-40th percentile
41-60th percentile
61-80th percentile
81-100th percentile
Haddock (*Melanogrammus aeglefinus*)

Haddock
(*Melanogrammus aeglefinus*)



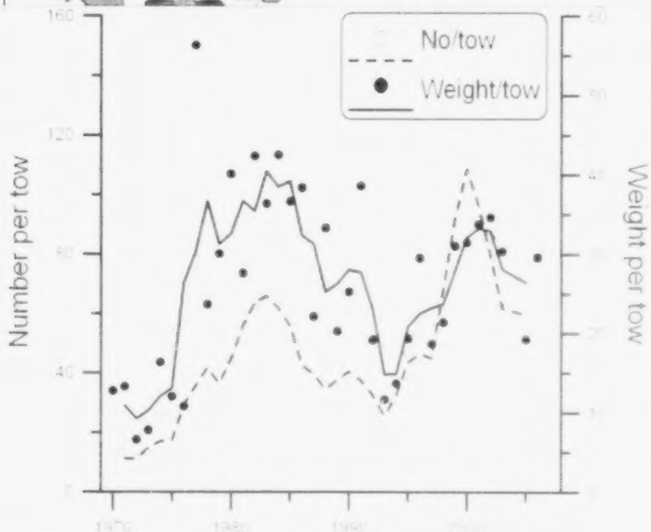
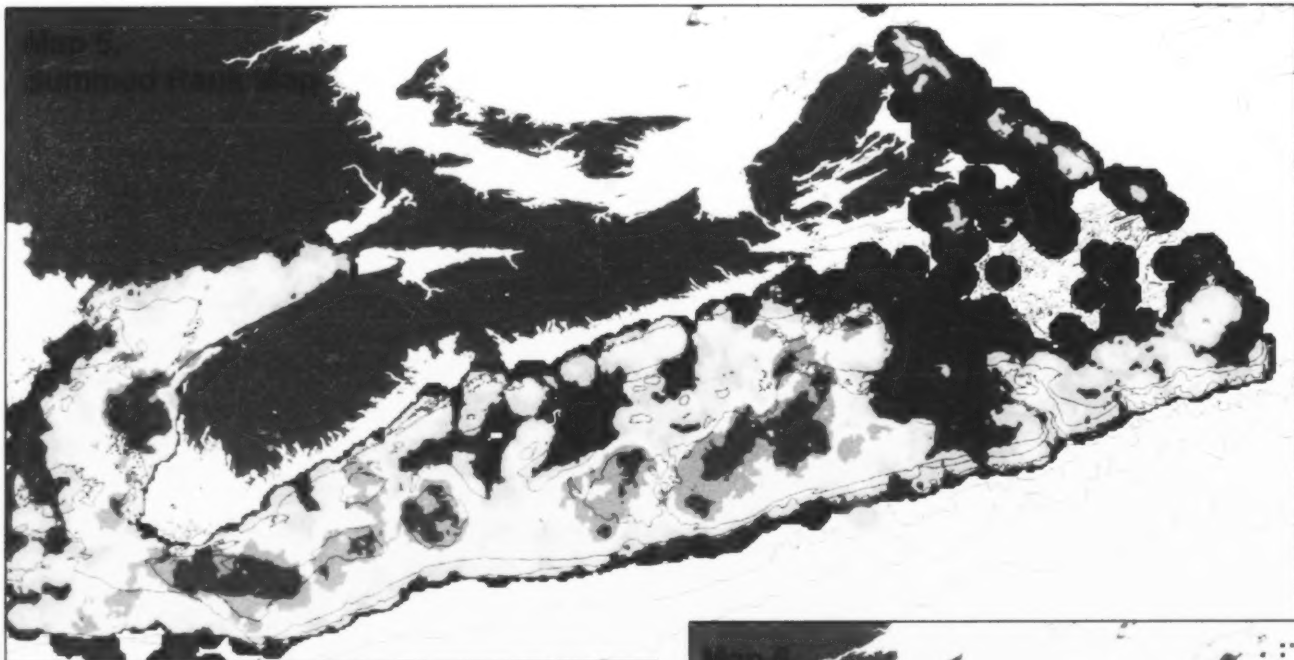


Figure 1. Population Trend

Haddock (*Melanogrammus aeglefinus*)



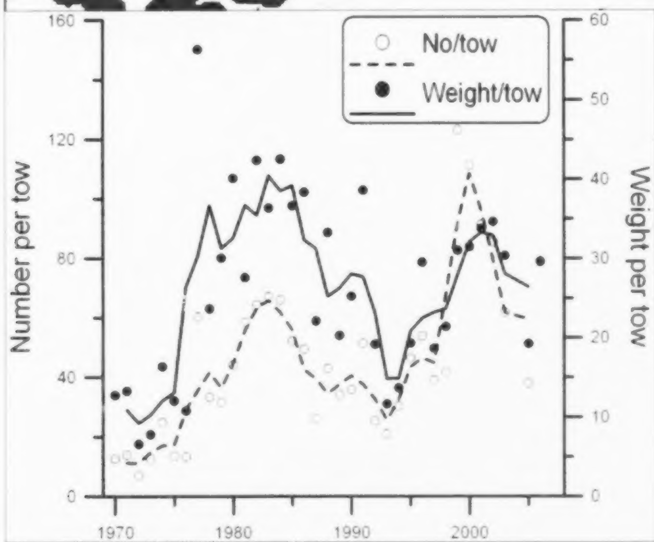
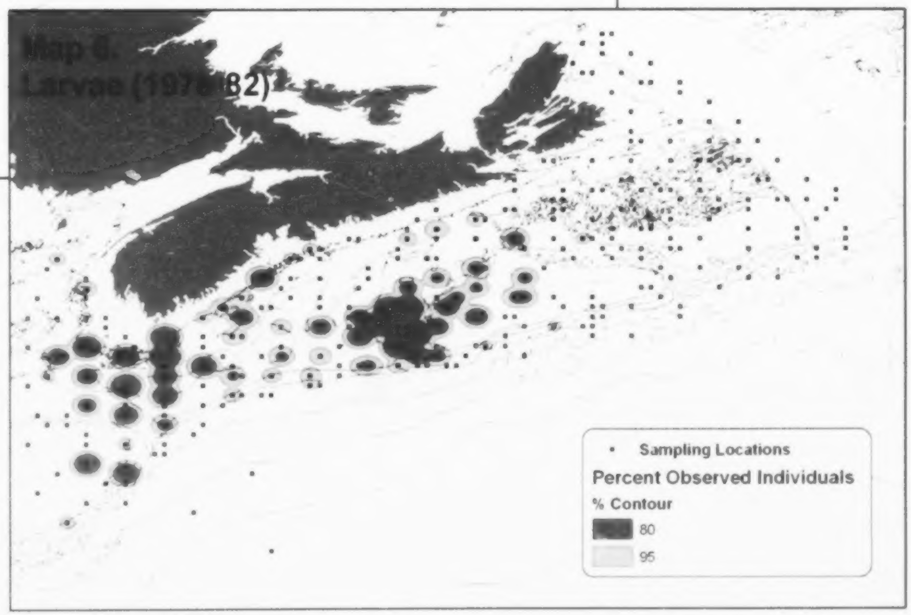
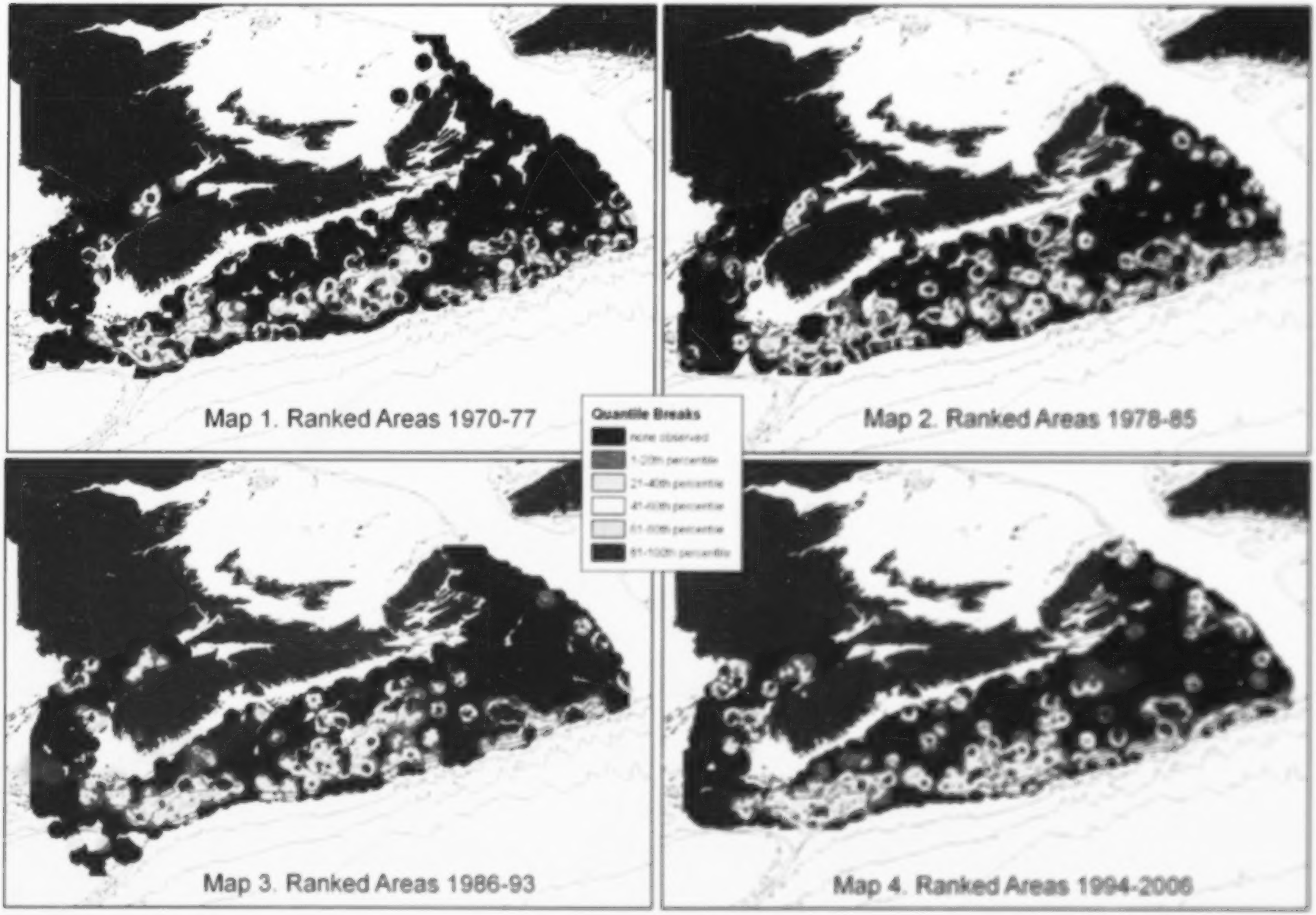
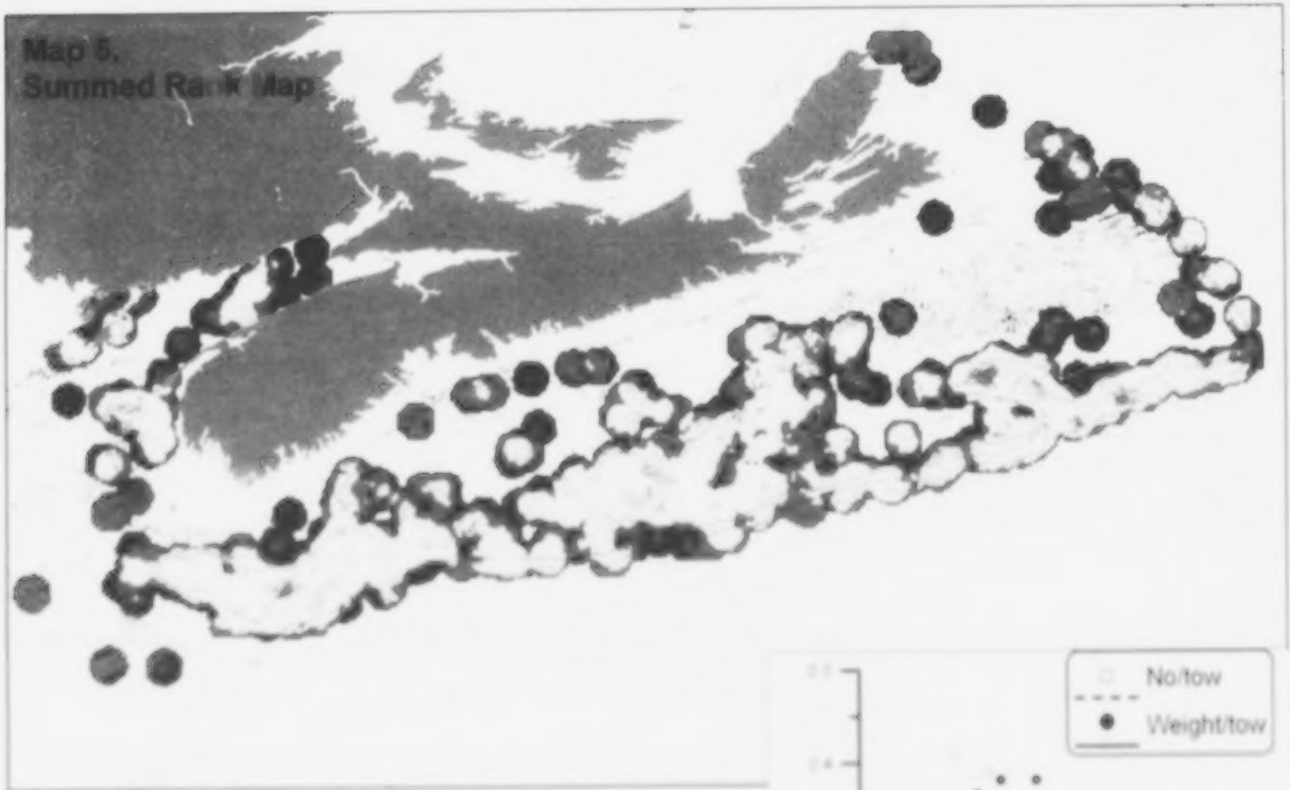


Figure 1. Population Trend



Halibut (*Hippoglossus hippoglossus*)





Halibut (*Hippoglossus hippoglossus*)

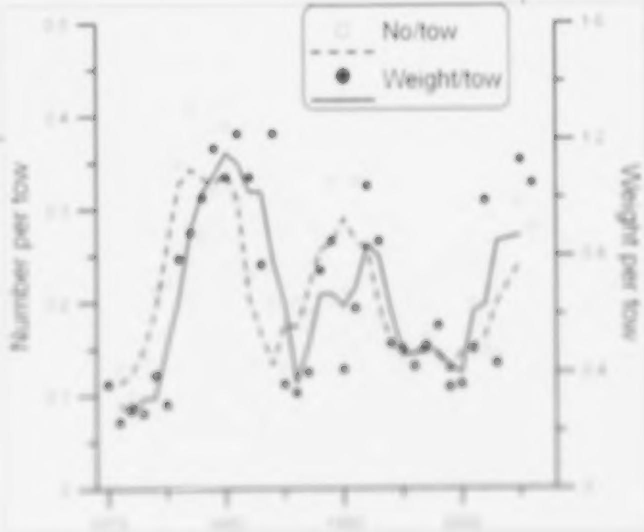
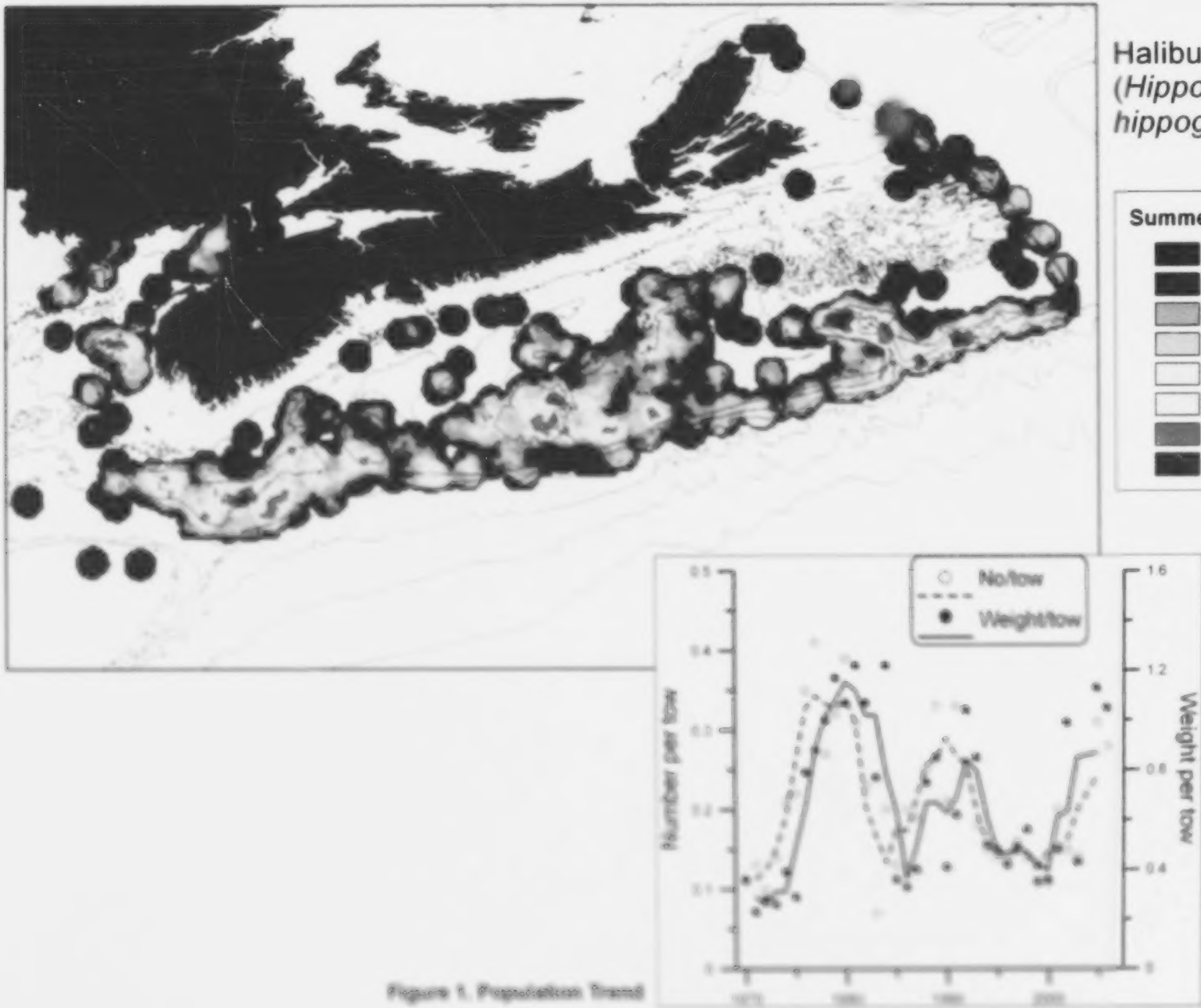


Figure 1. Population Trend

Halibut
(*Hippoglossus hippoglossus*)



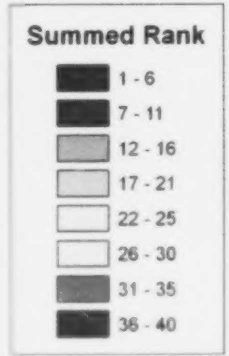
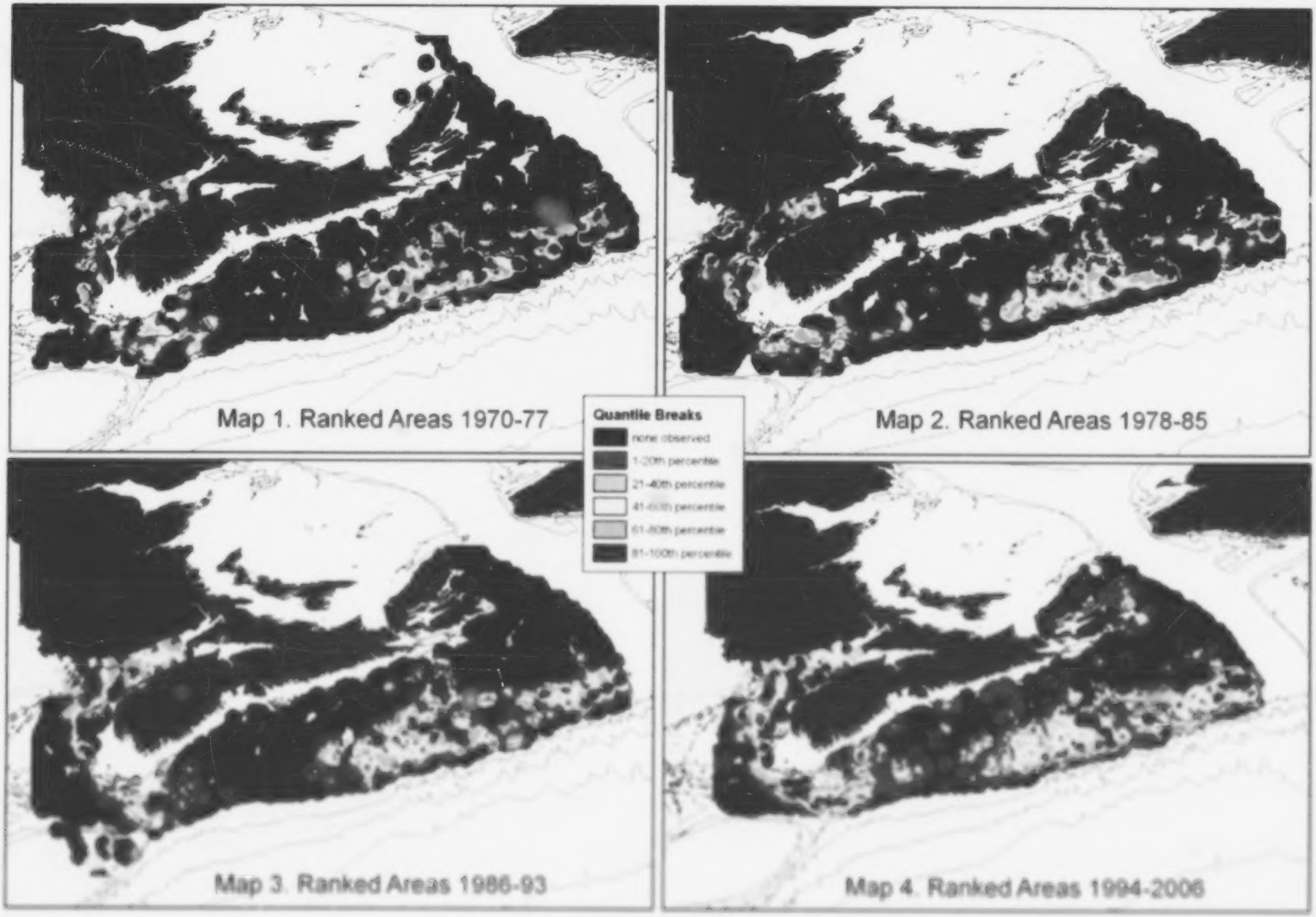
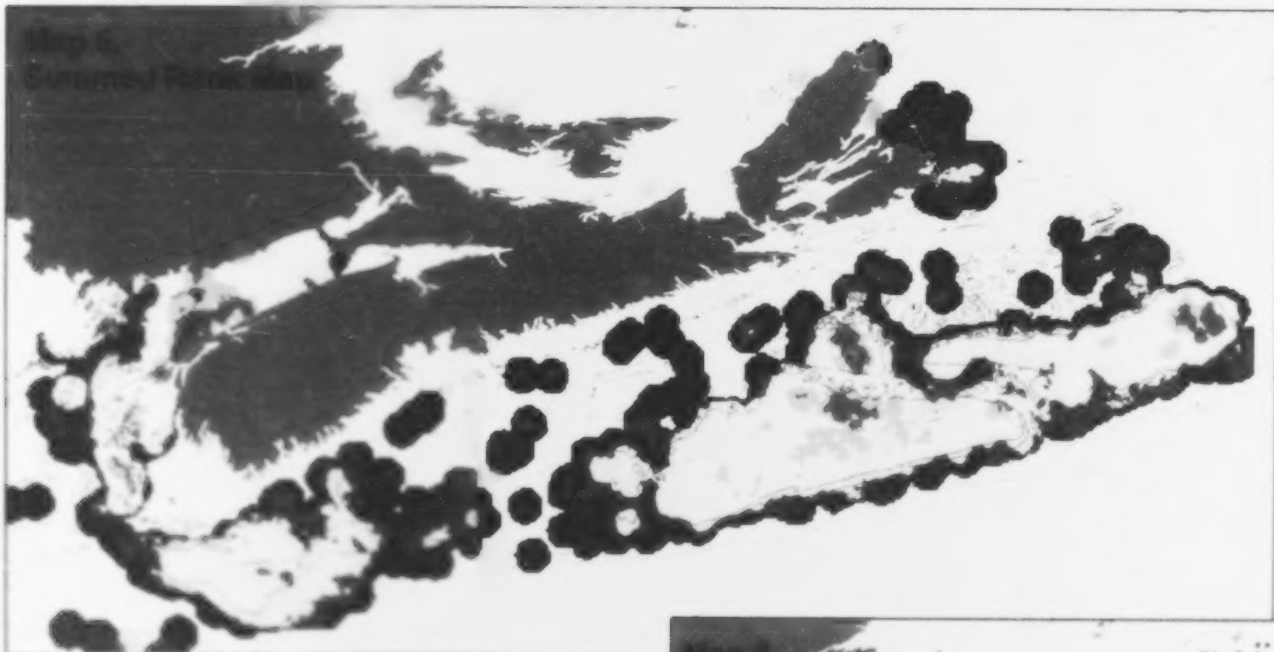


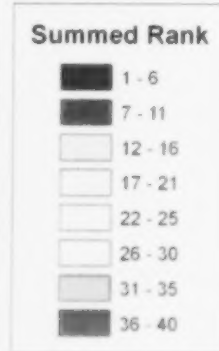
Figure 1. Population Trend

Longhorn Sculpin (*Myoxocephalus octodecemspinosus*)



Longhorn Sculpin (*Myoxocephalus octodecemspinosus*)





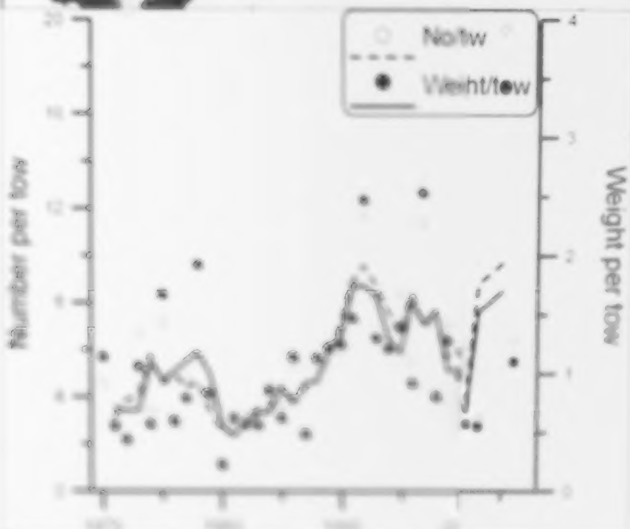
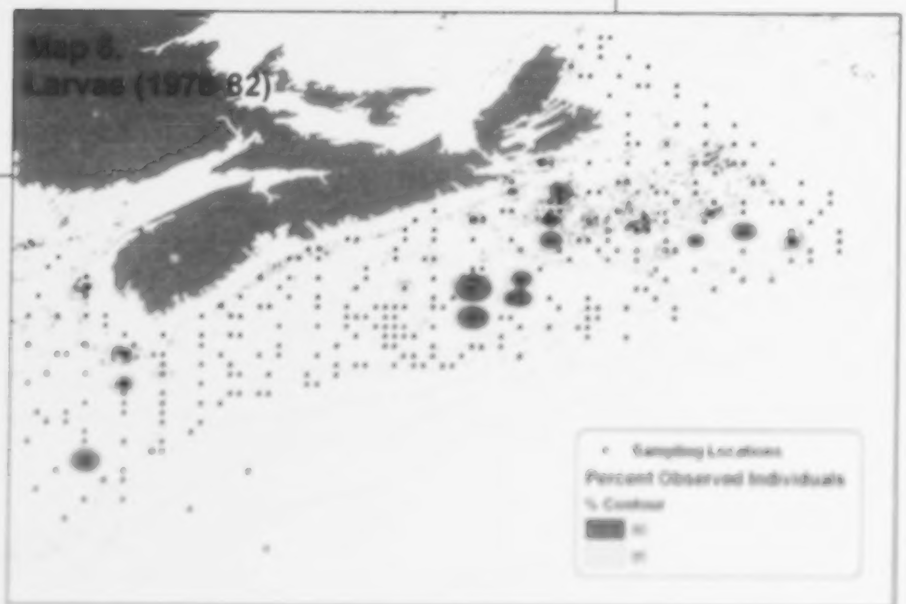


Figure 1. Population Trend



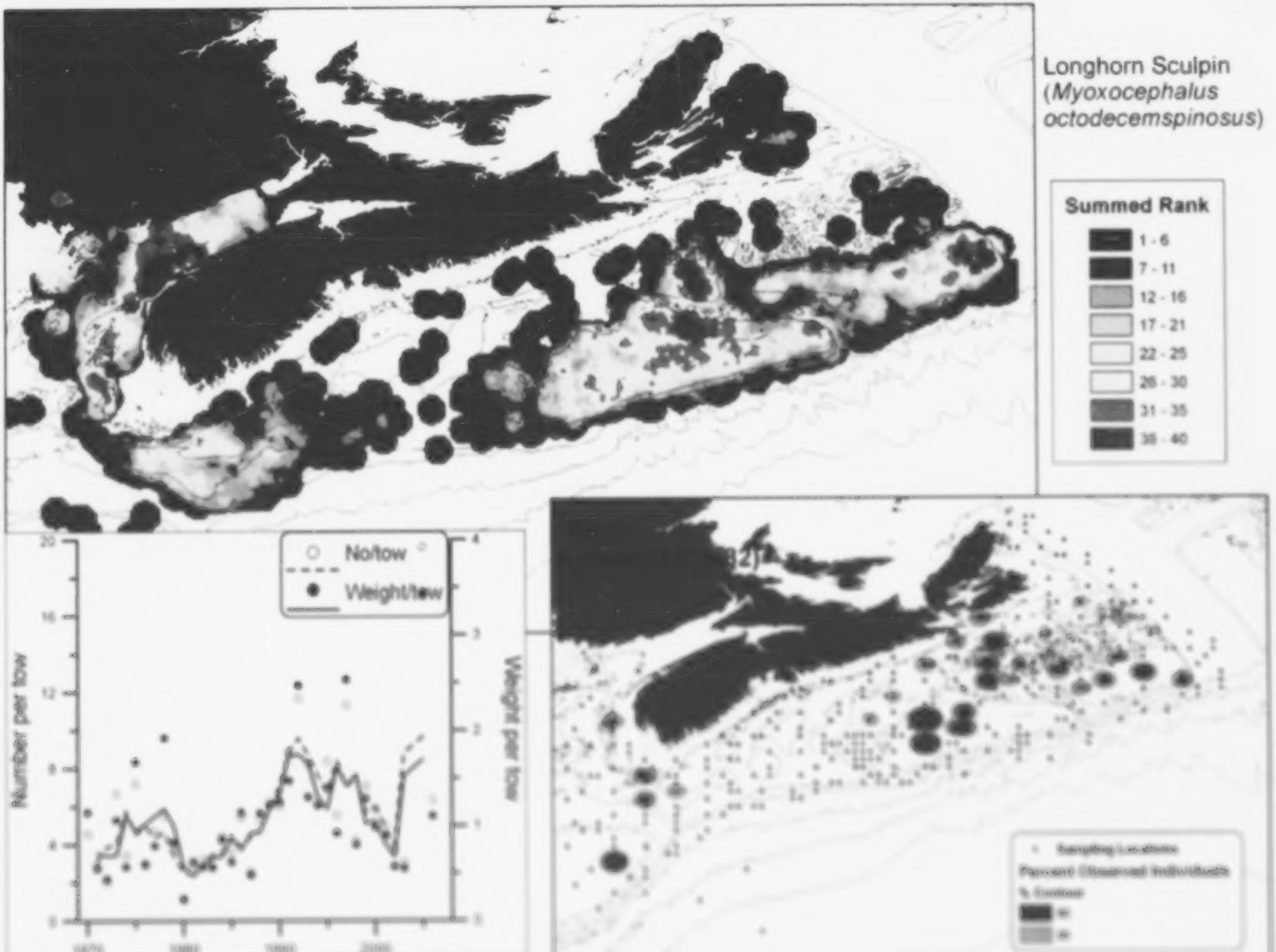
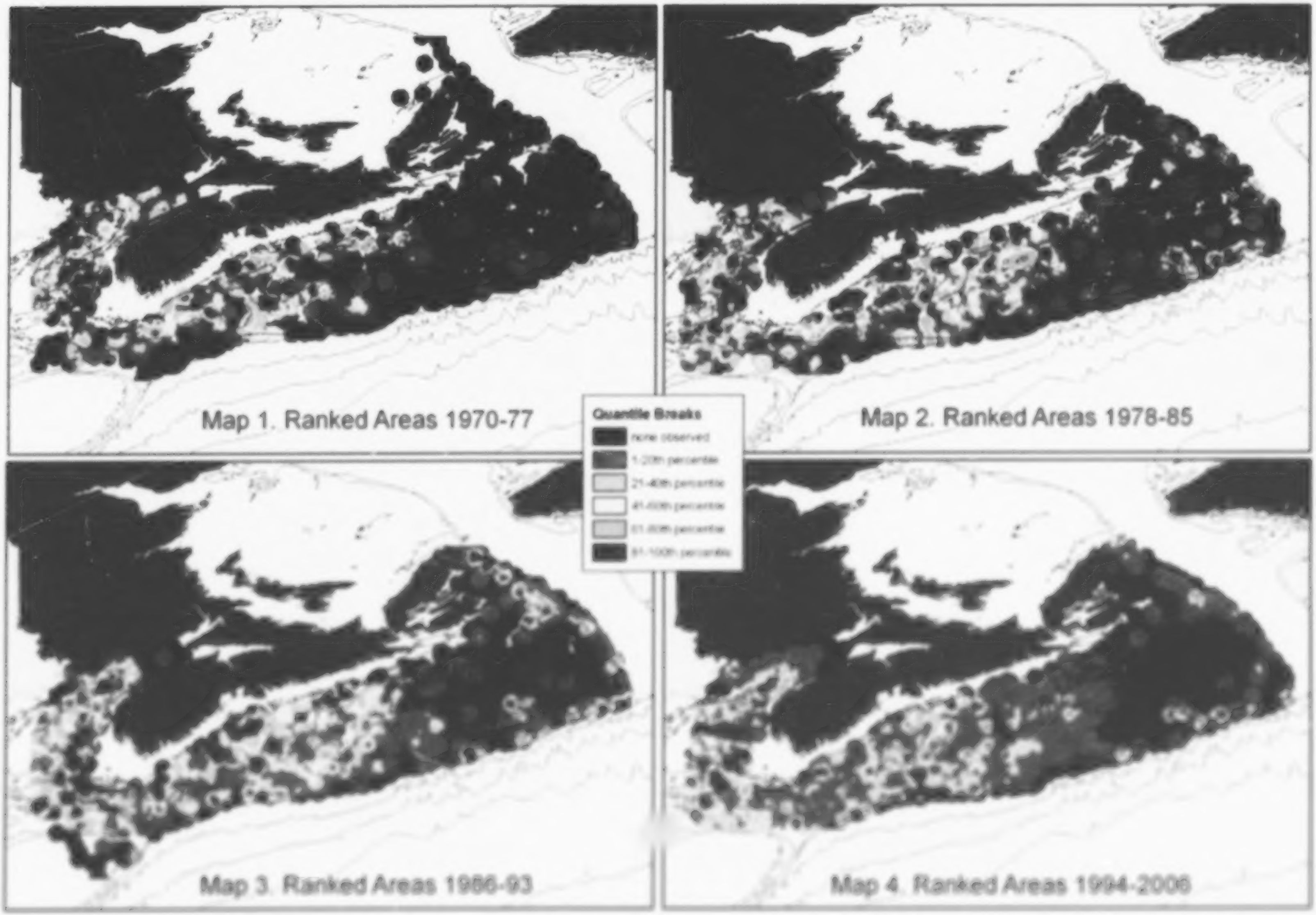
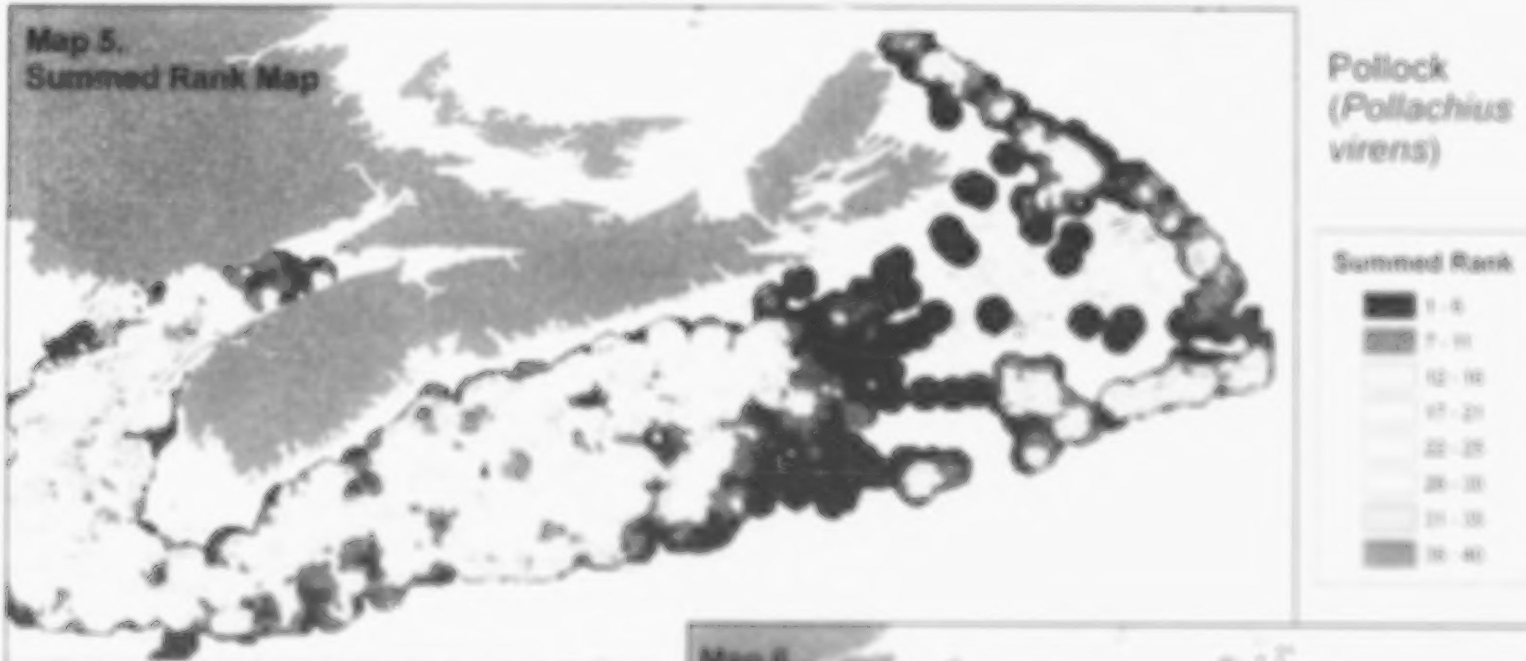


Figure 1. Population Trend

Pollock (*Pollachius virens*)



Pollock (*Pollachius virens*)



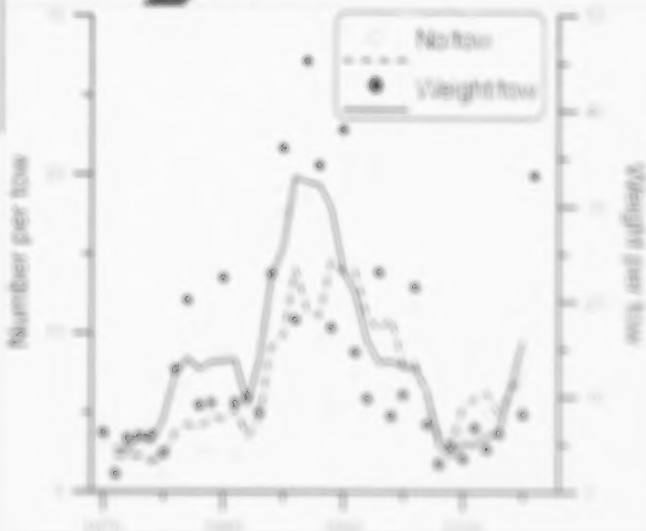
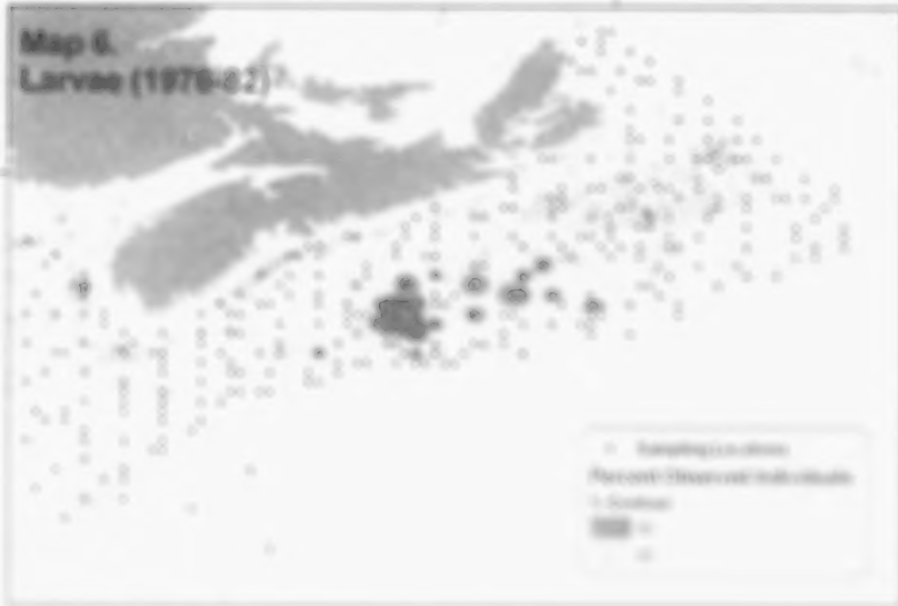
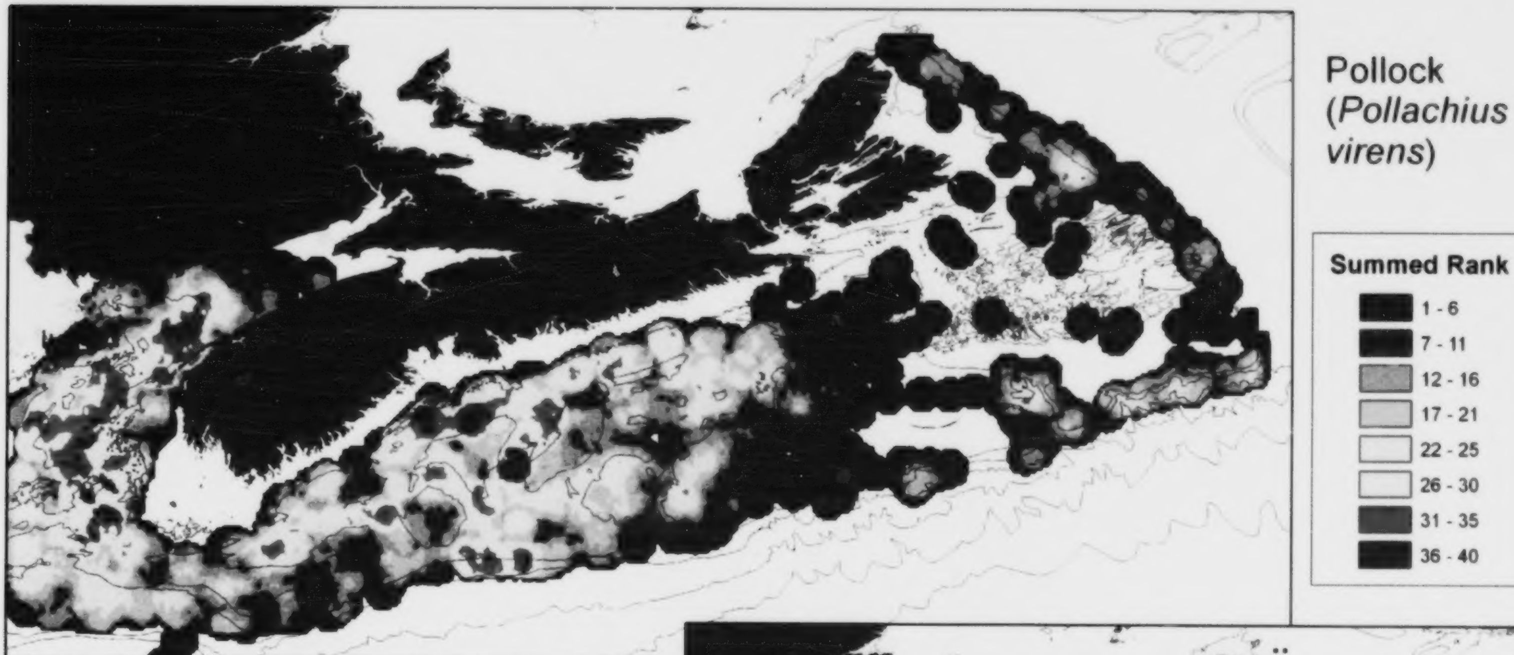


Figure 1. Population Trend



Pollock (*Pollachius virens*)



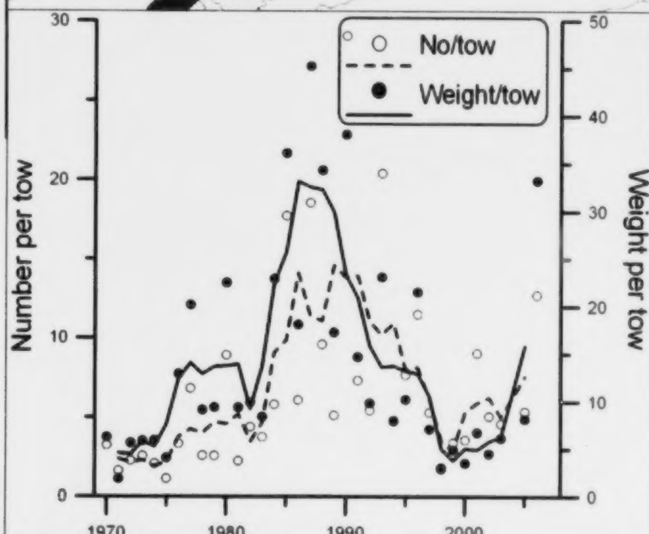
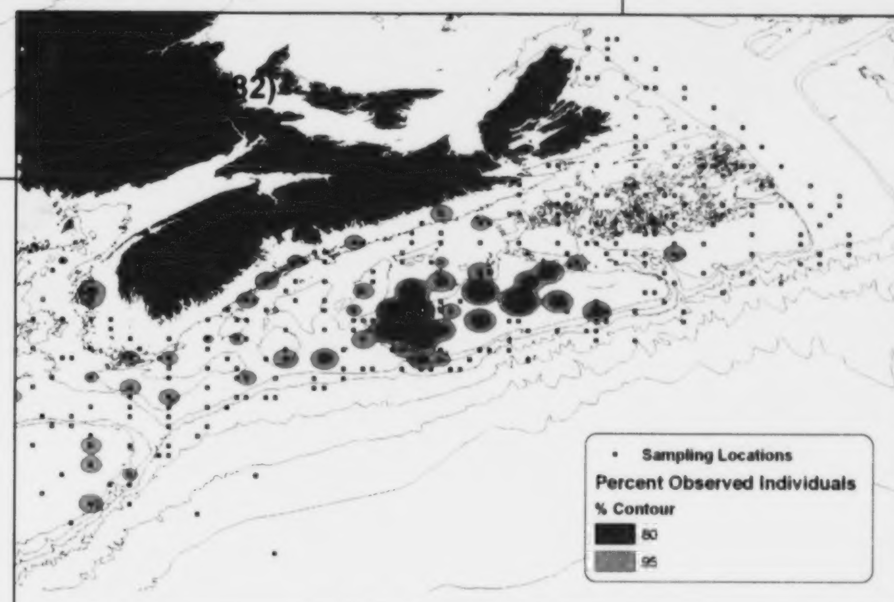
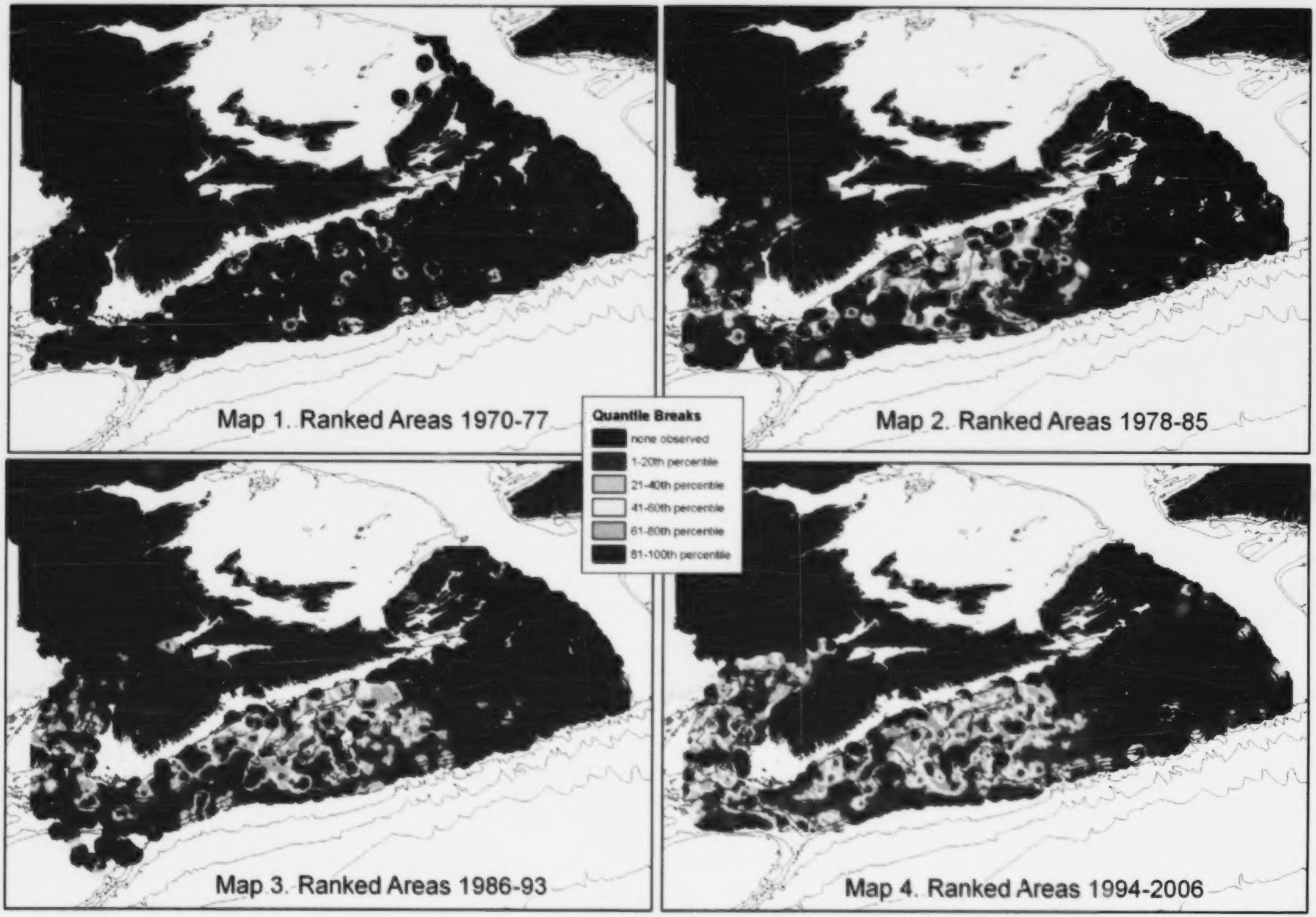


Figure 1. Population Trend





Red Hake (*Urophycis chuss*)

Red Hake
(*Urophycis chuss*)

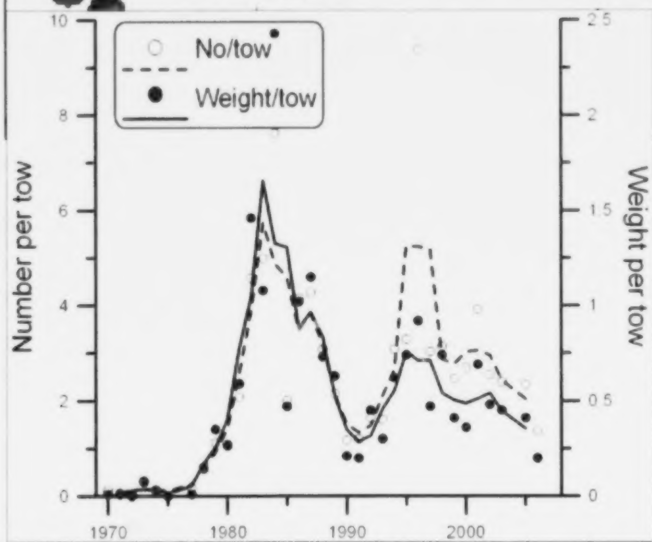
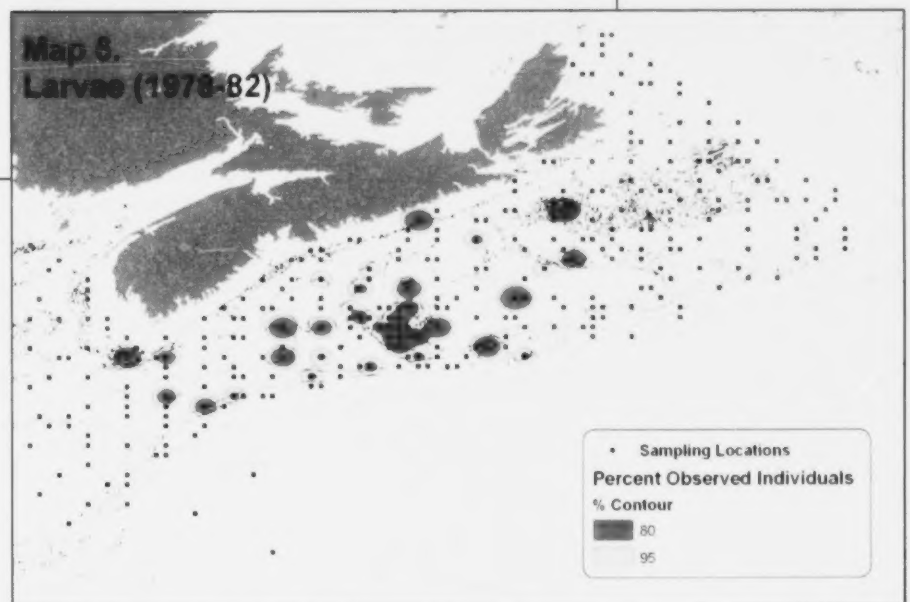
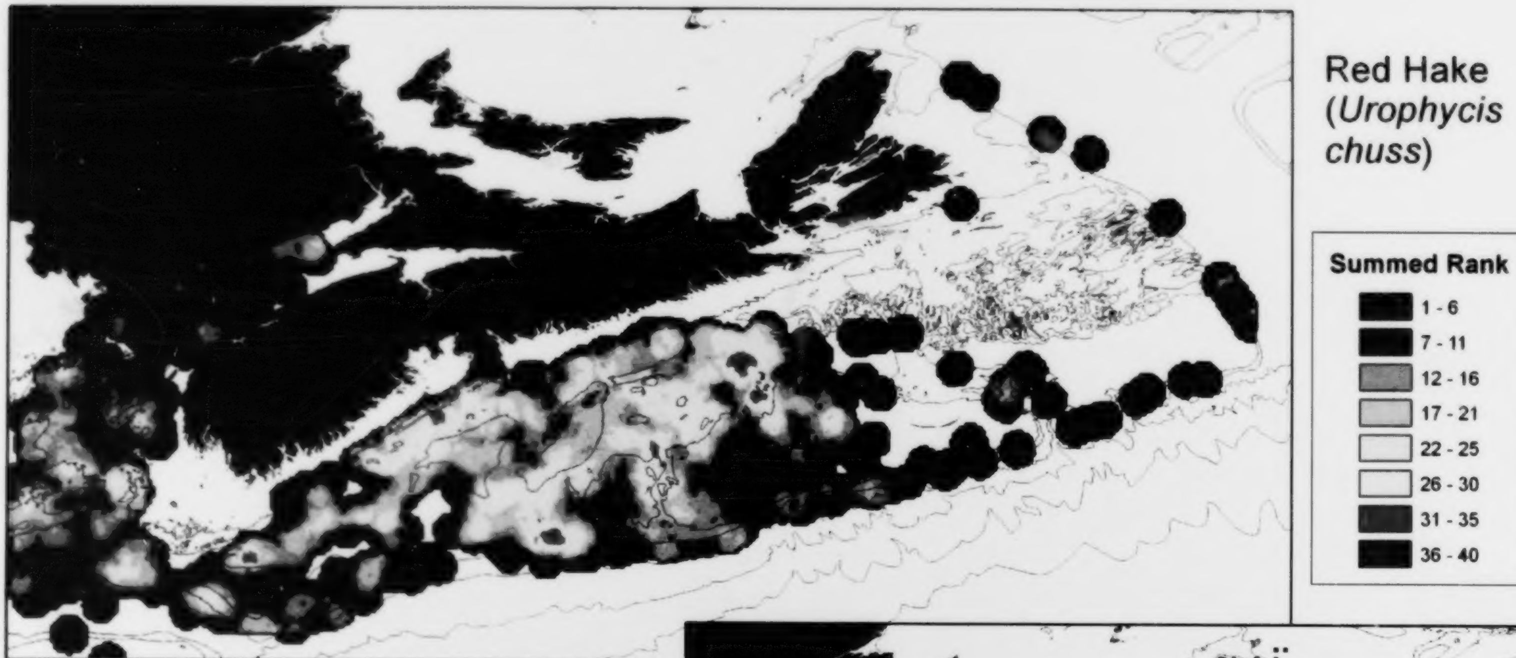


Figure 1. Population Trend



Red Hake (*Urophycis chuss*)



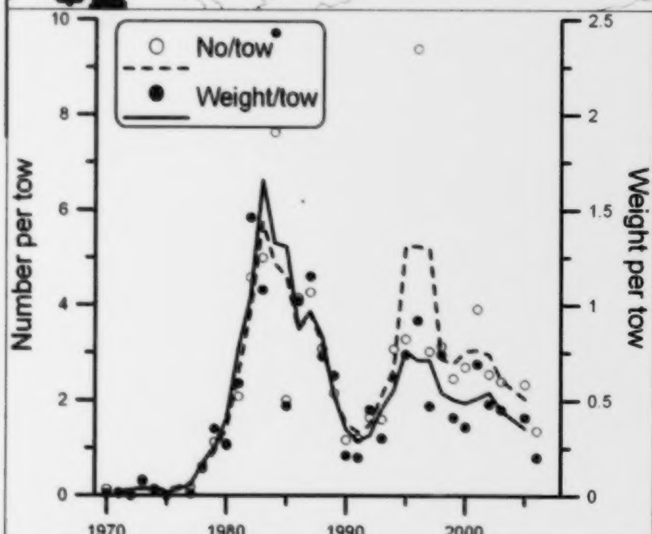
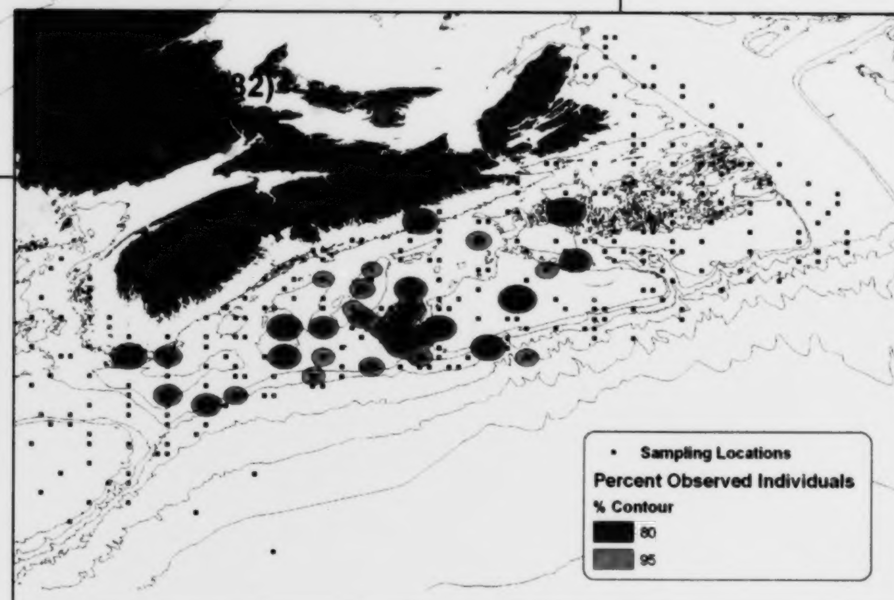
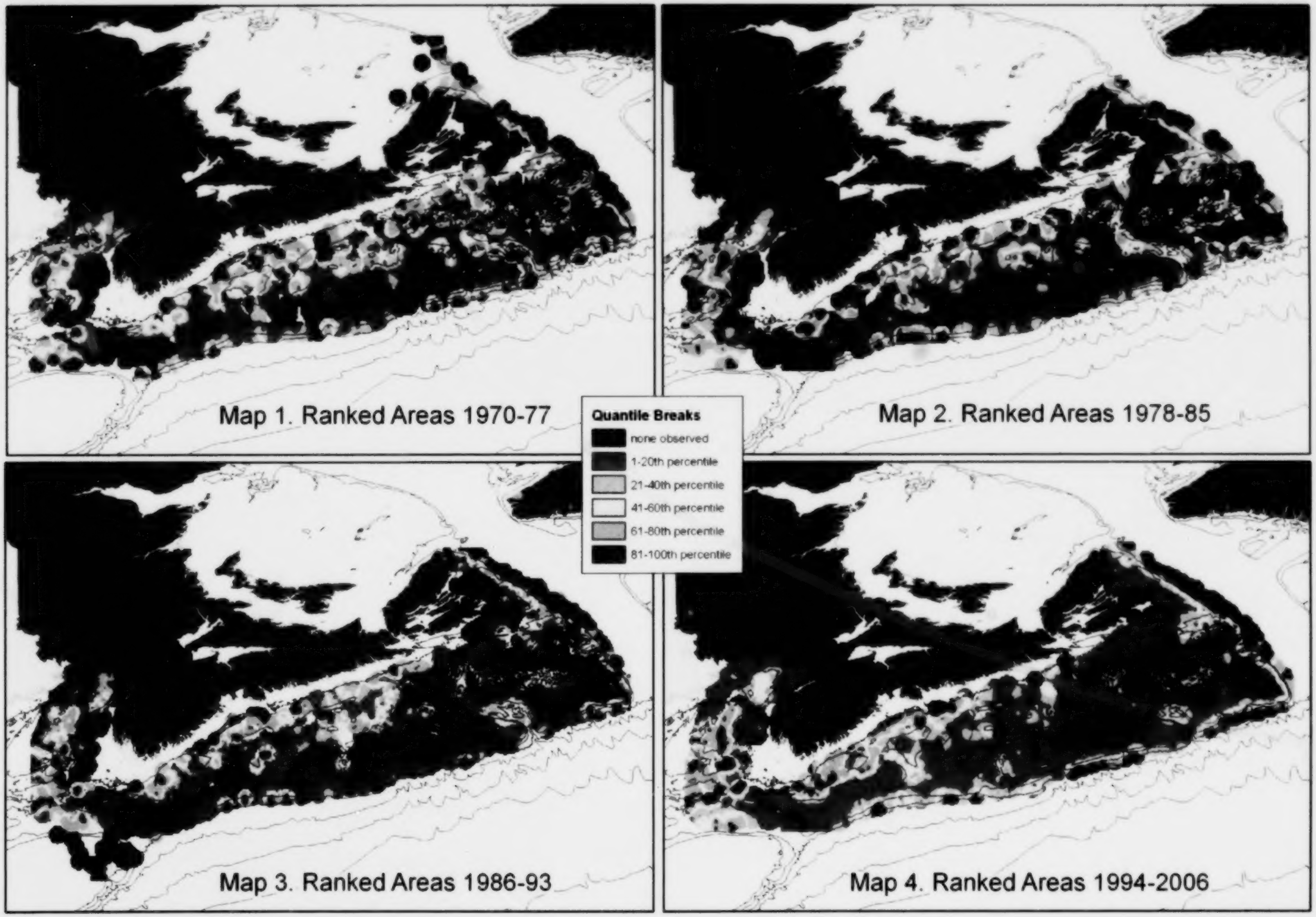


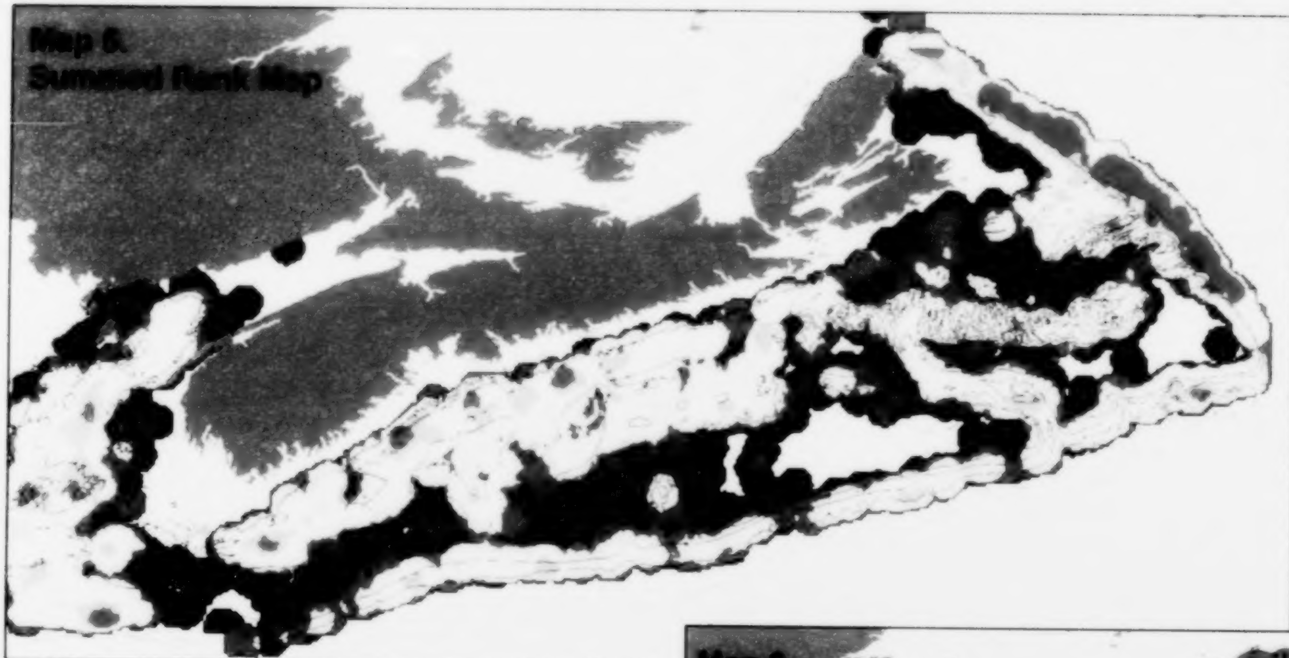
Figure 1. Population Trend





Redfish (*Sebastes spp*)

Redfish
(*Sebastes spp*)



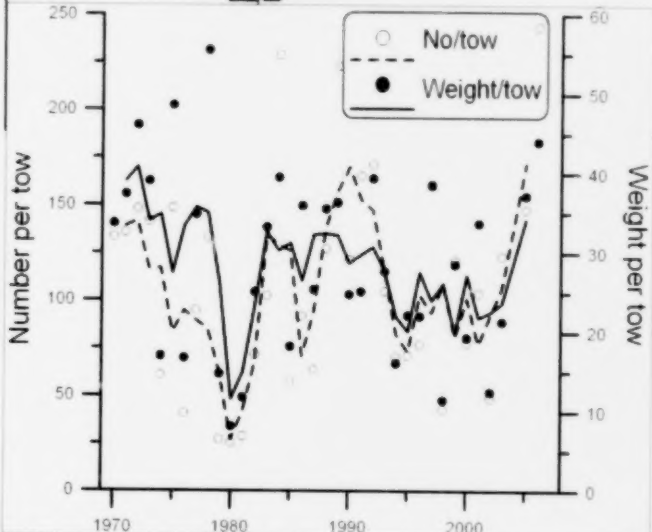
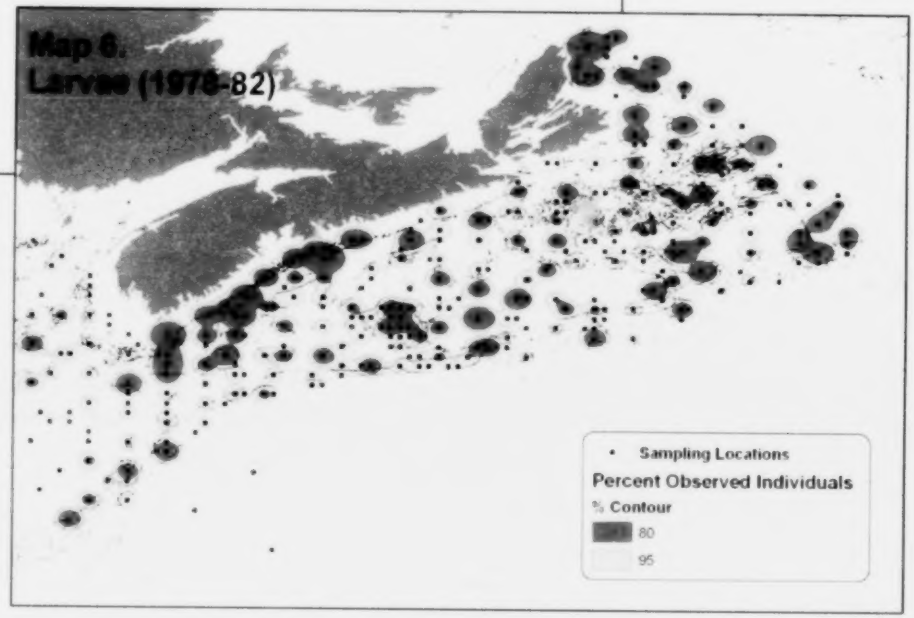
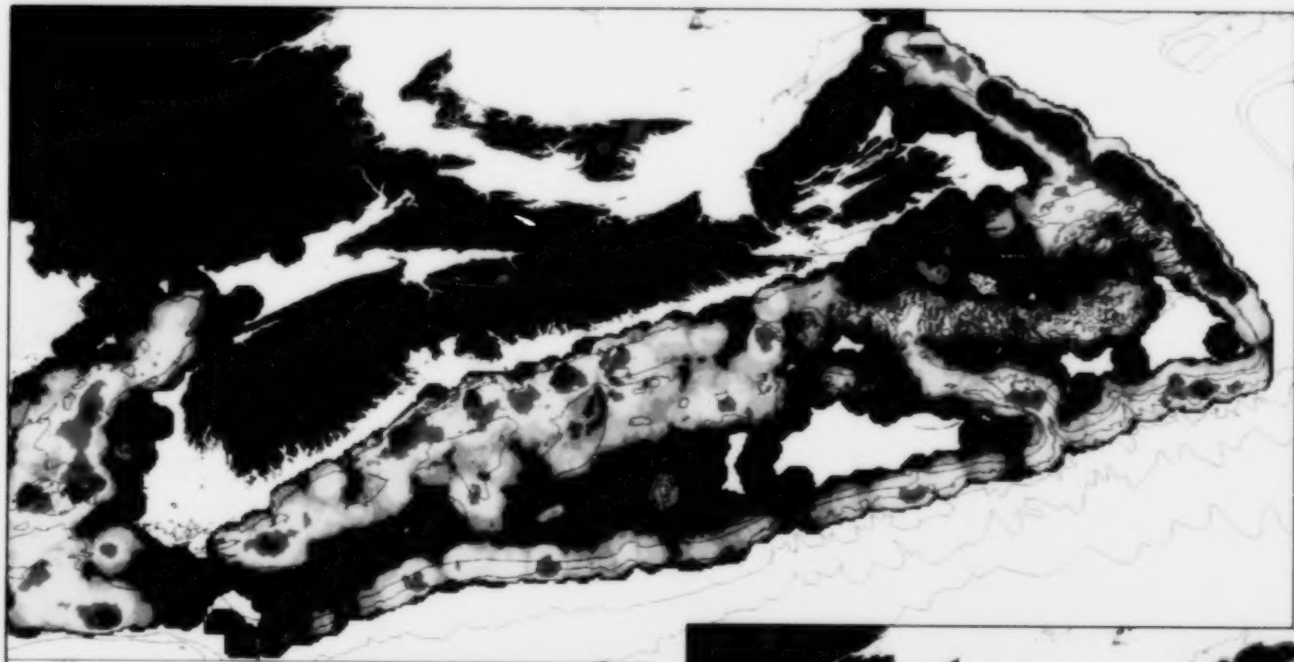


Figure 1. Population Trend



Redfish (*Sebastes spp*)



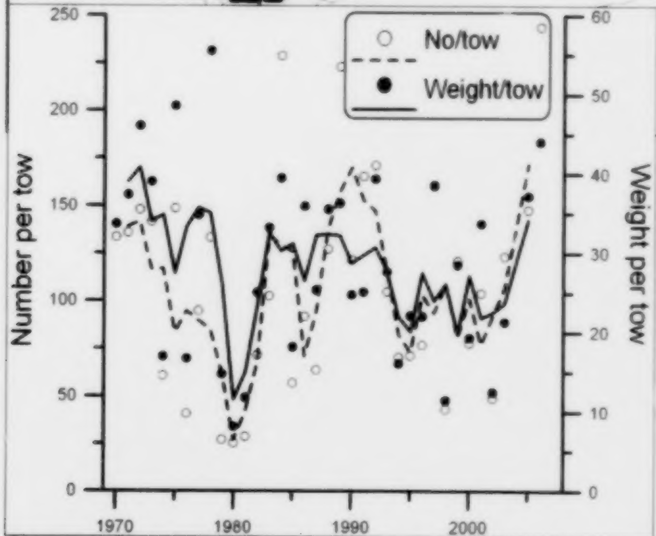
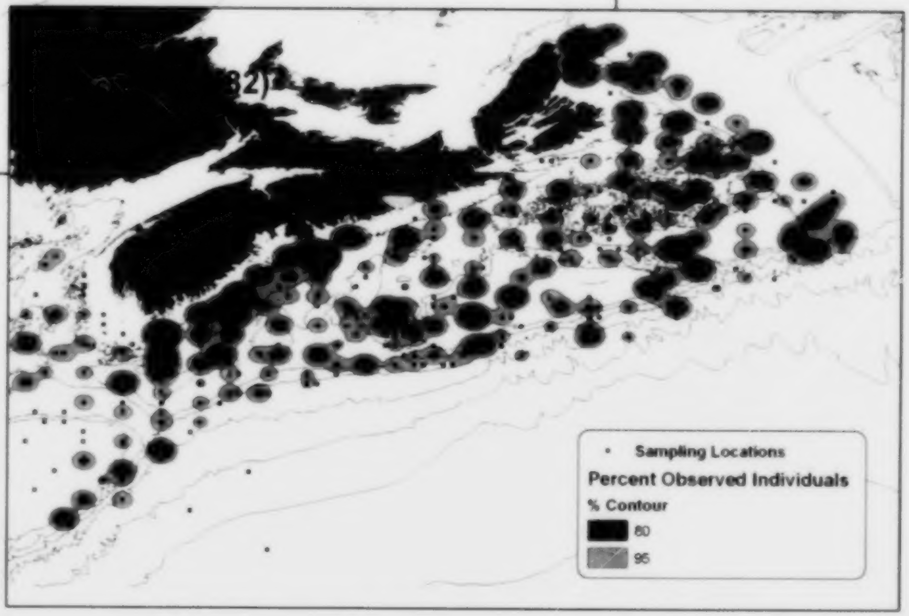
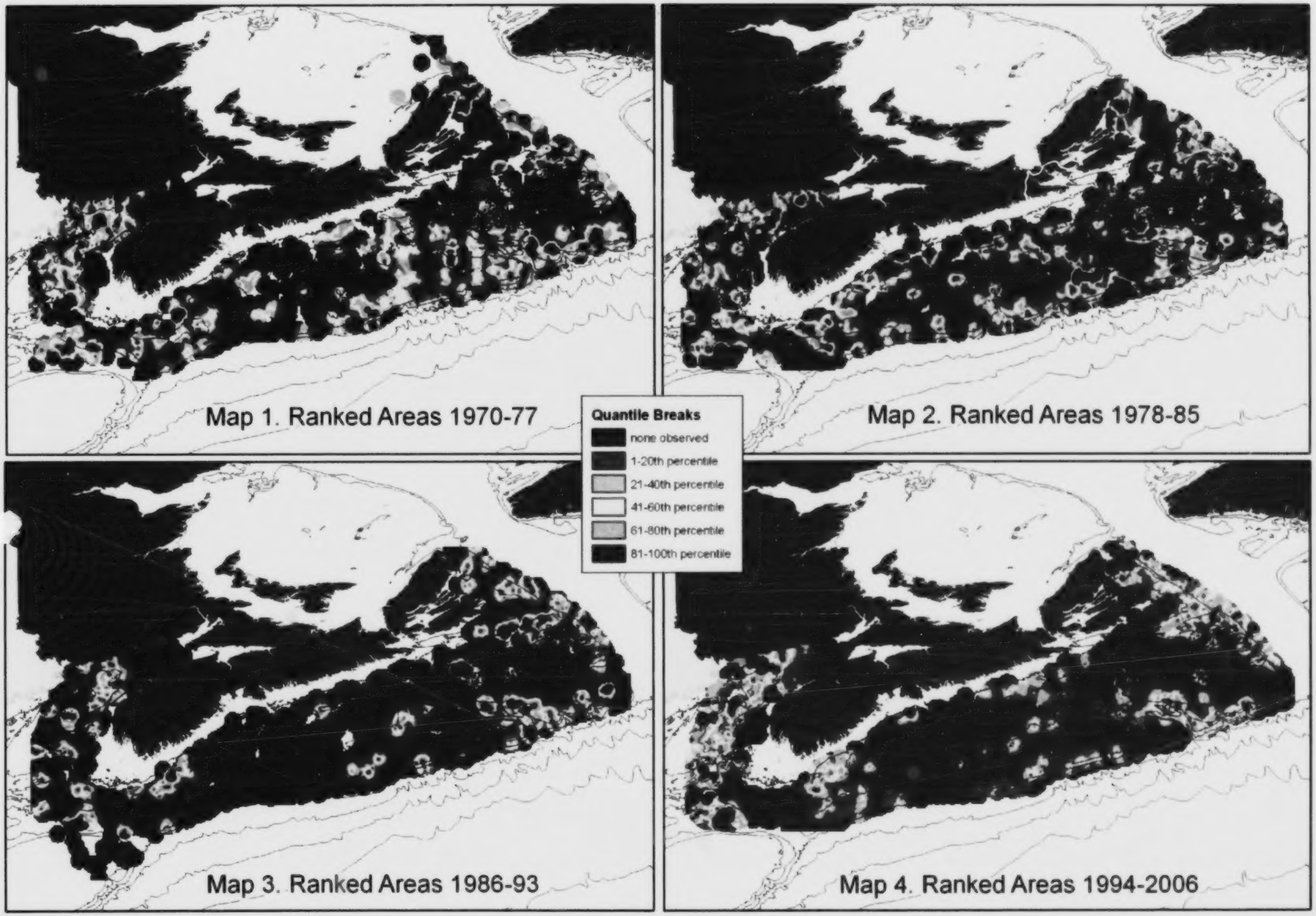


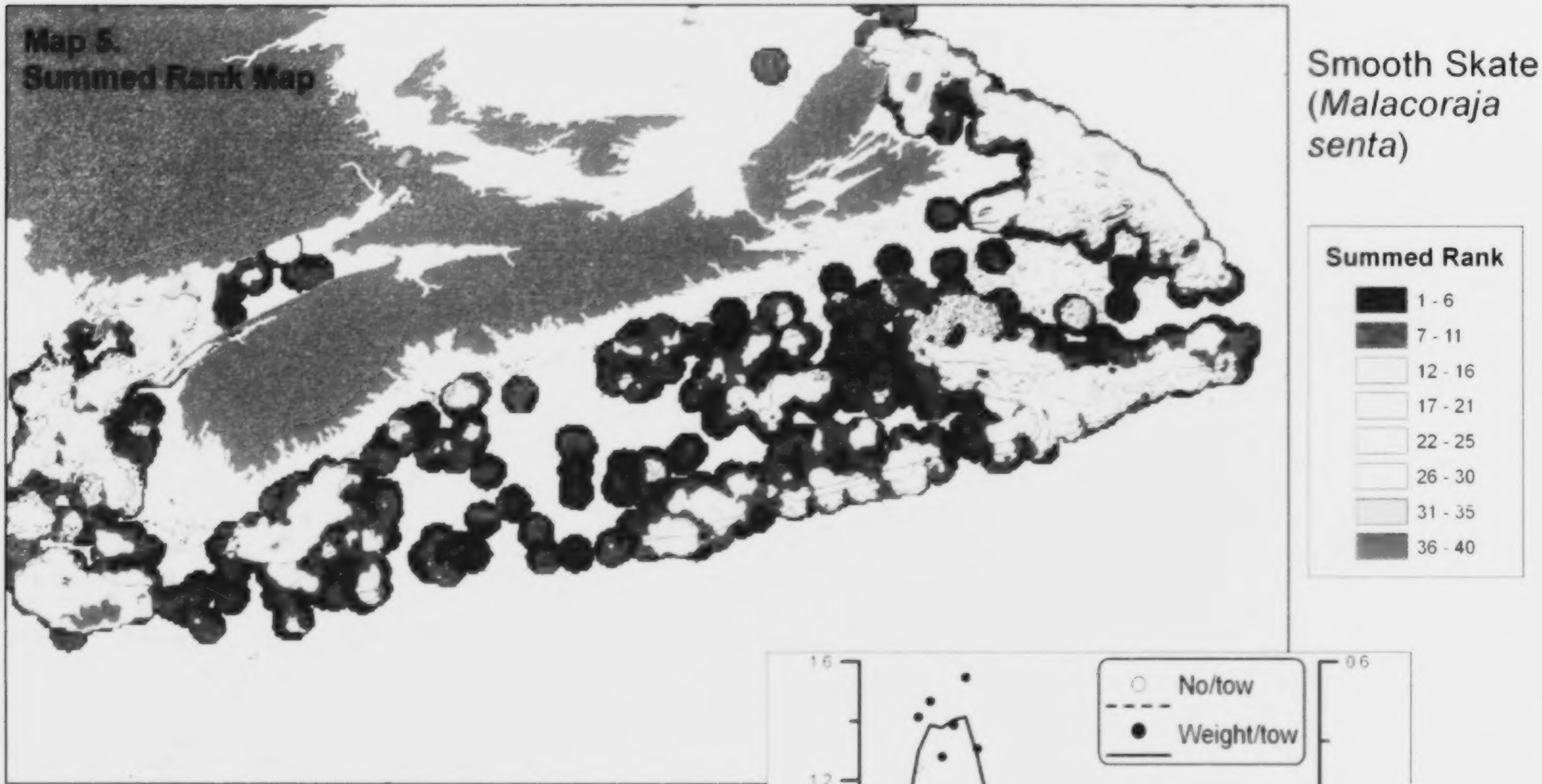
Figure 1. Population Trend





Smooth Skate (*Malacoraja senta*)

Smooth Skate (*Malacoraja senta*)



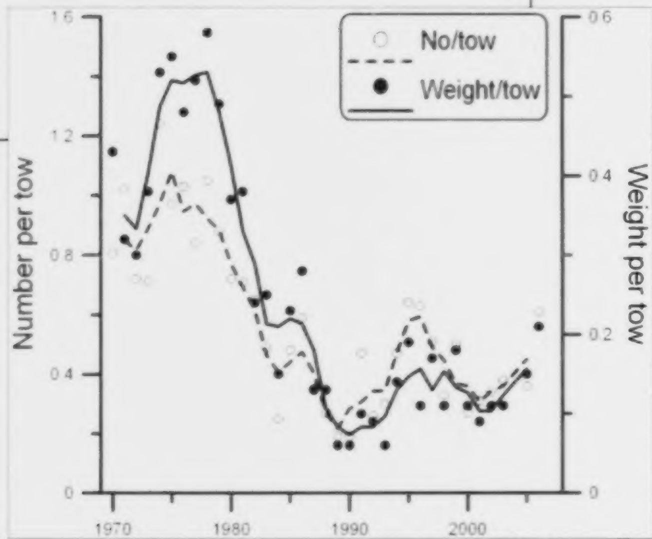
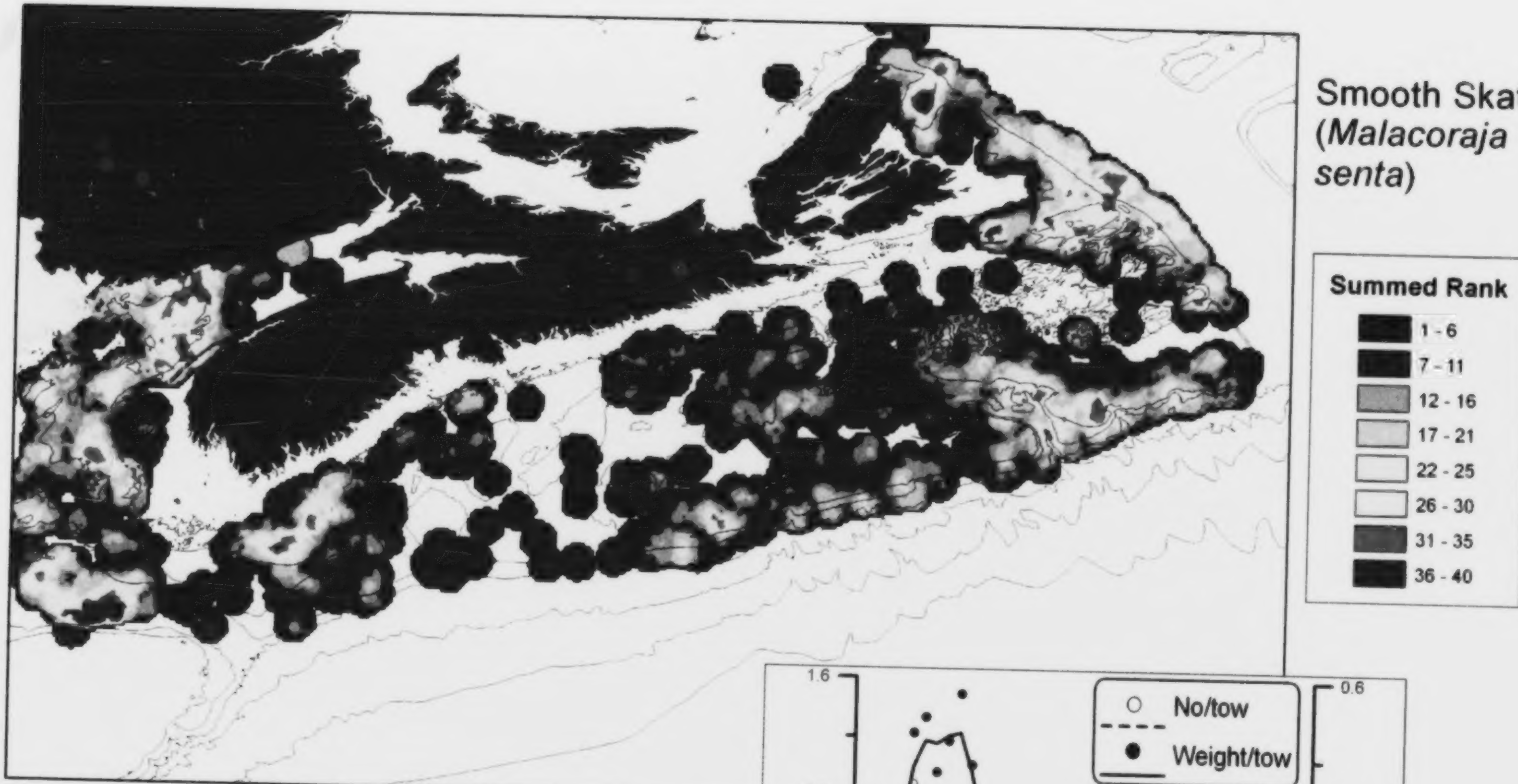


Figure 1. Population Trend

Smooth Skate (*Malacoraja senta*)



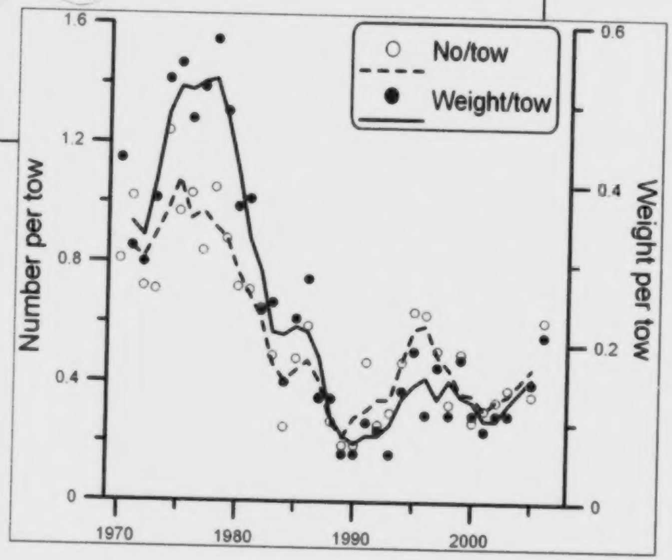
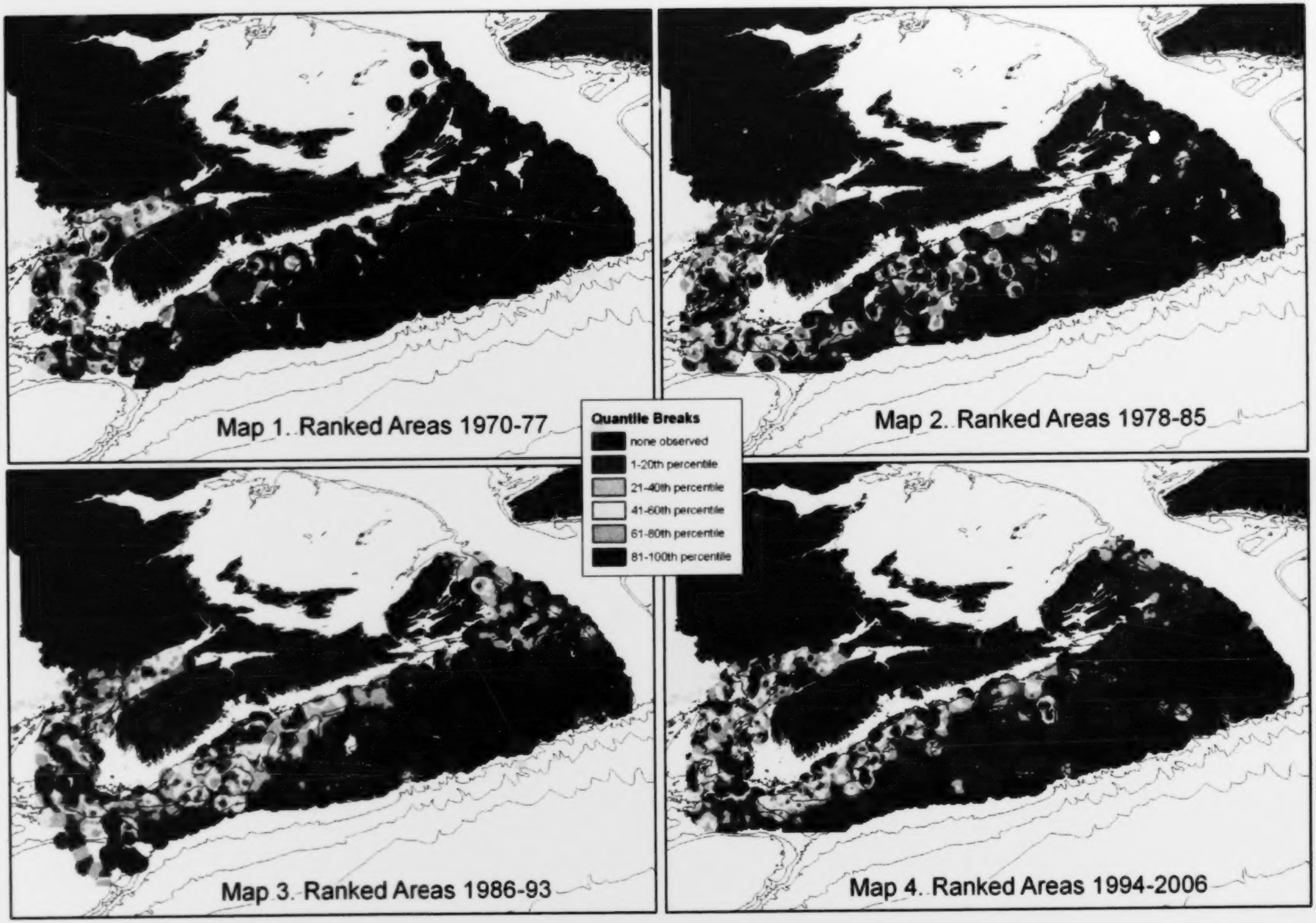
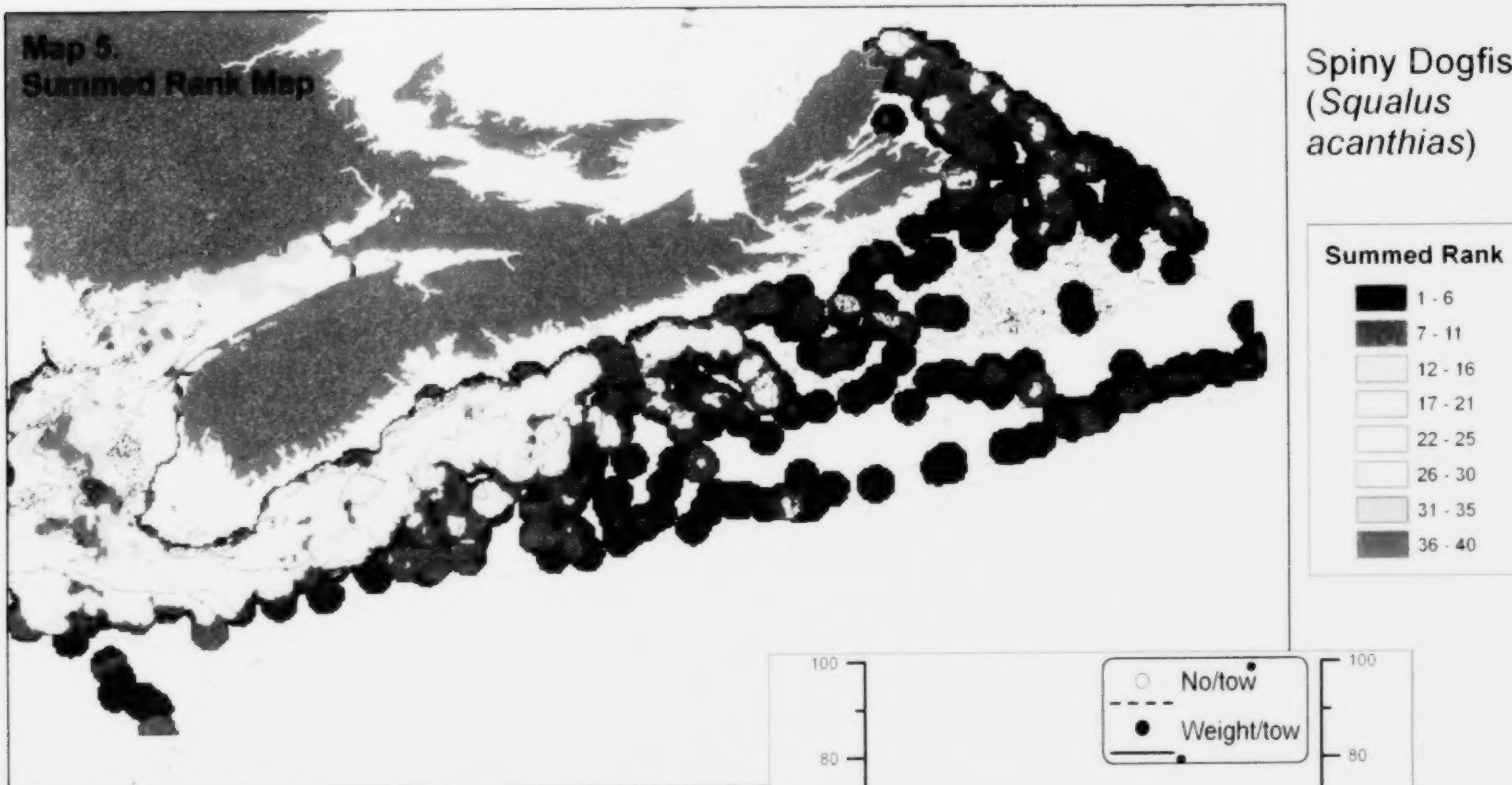


Figure 1. Population Trend



Spiny Dogfish (*Squalus acanthias*)

Spiny Dogfish (*Squalus acanthias*)



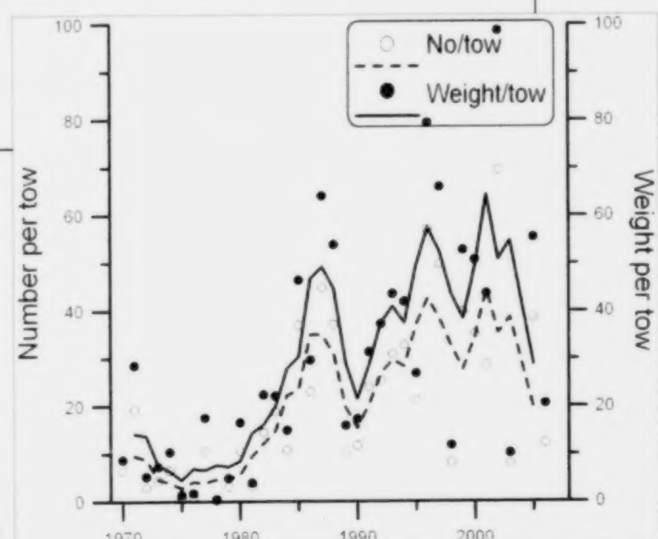
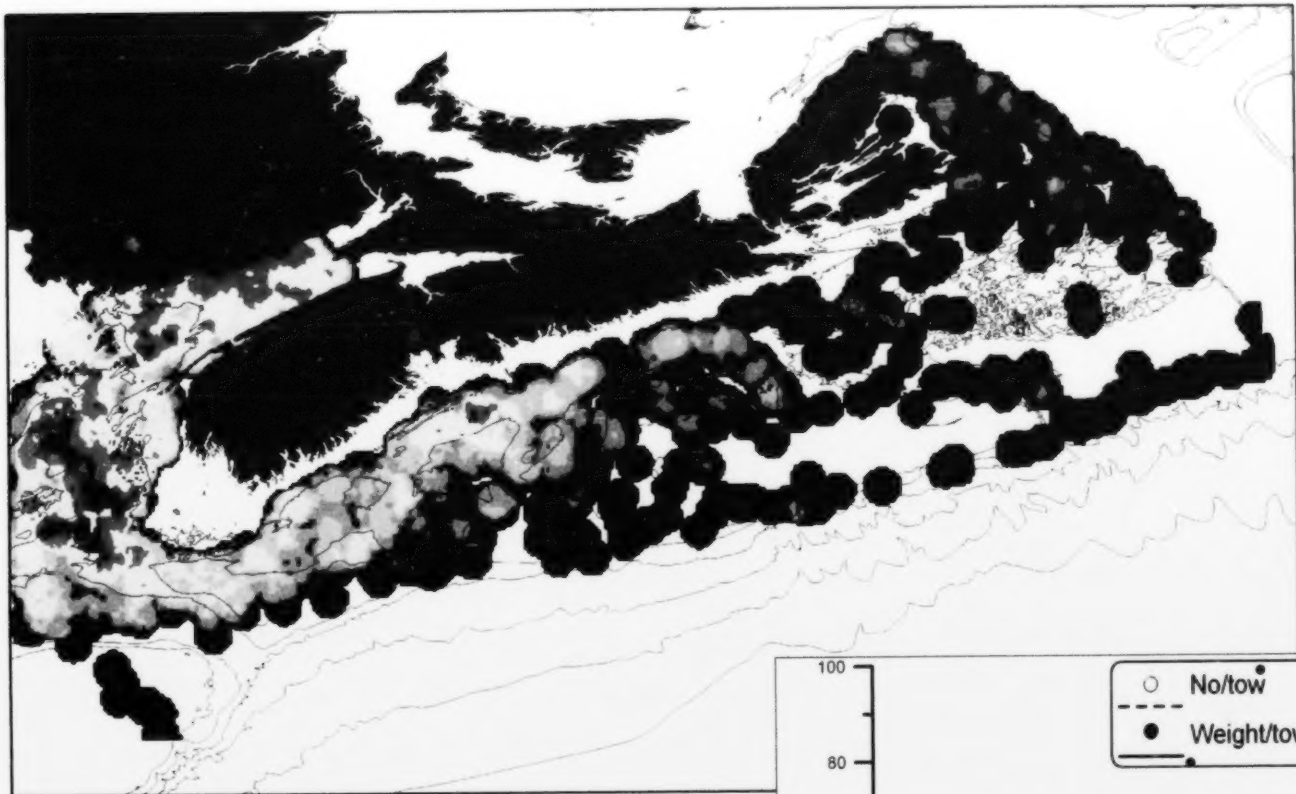


Figure 1. Population Trend

Spiny Dogfish (*Squalus acanthias*)



Summed Rank

- 1 - 6
- 7 - 11
- 12 - 16
- 17 - 21
- 22 - 25
- 26 - 30
- 31 - 35
- 36 - 40

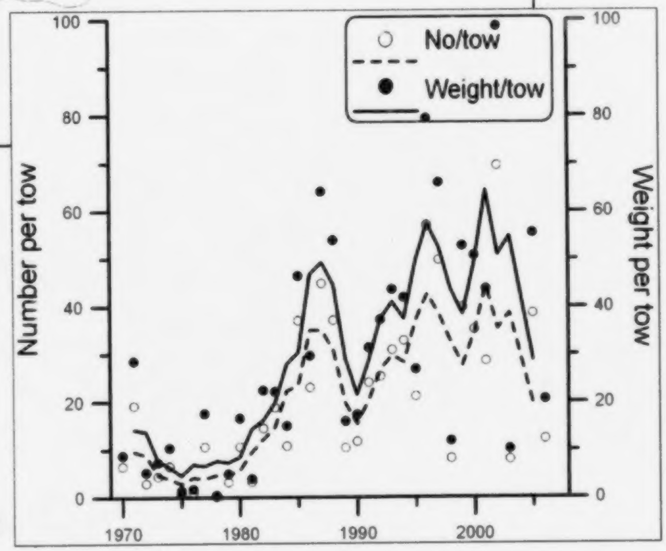
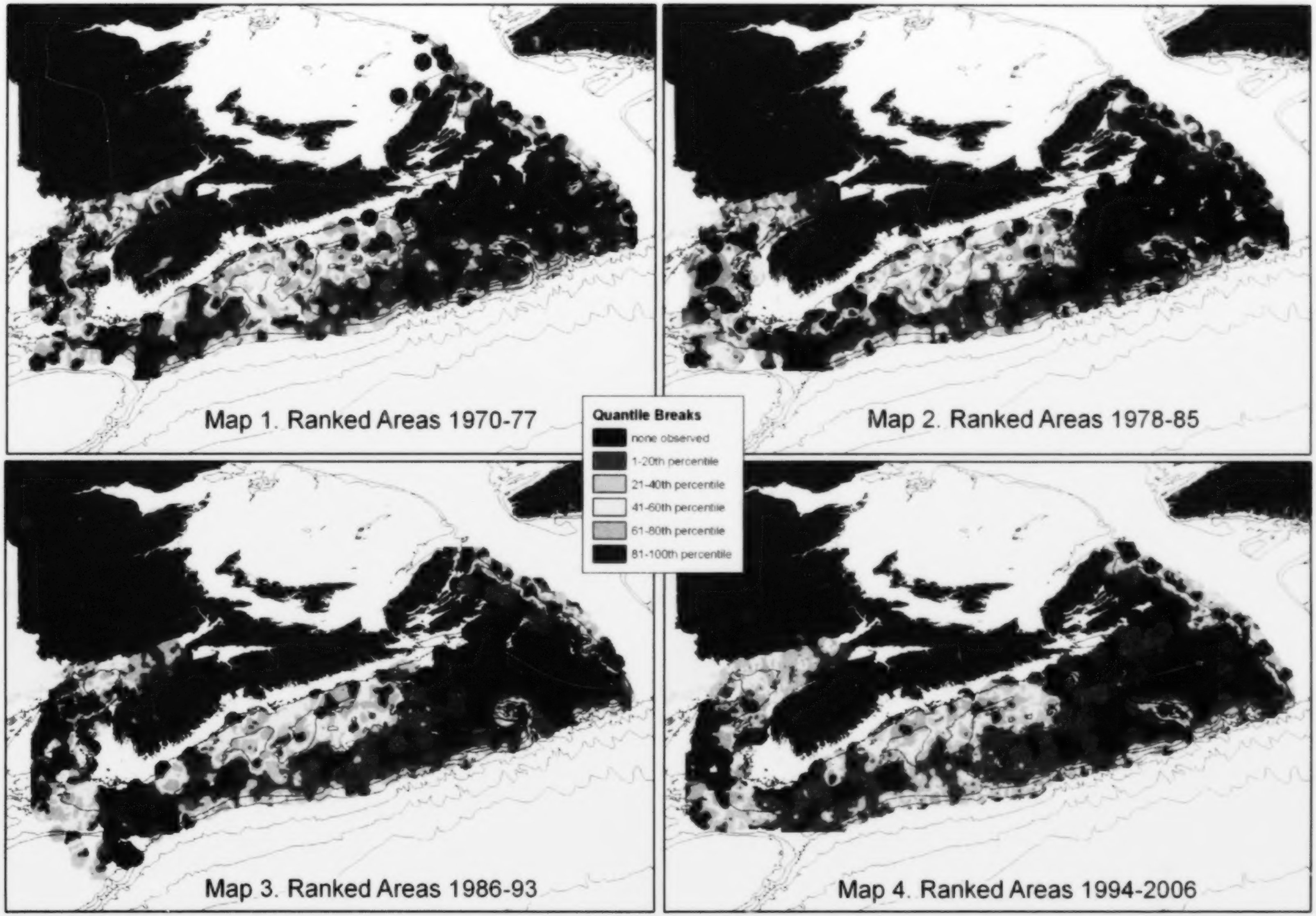
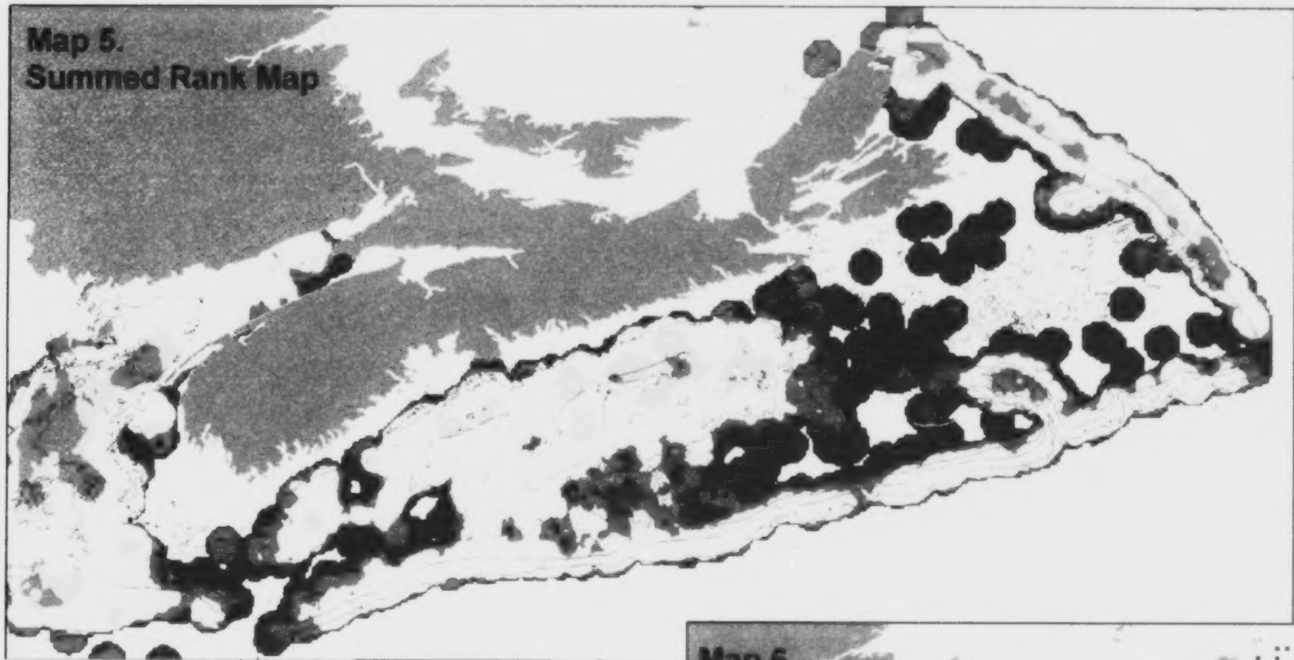


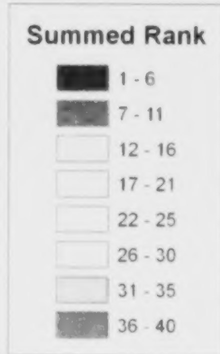
Figure 1. Population Trend

White Hake (*Urophycis tenuis*)



White Hake (*Urophycis tenuis*)





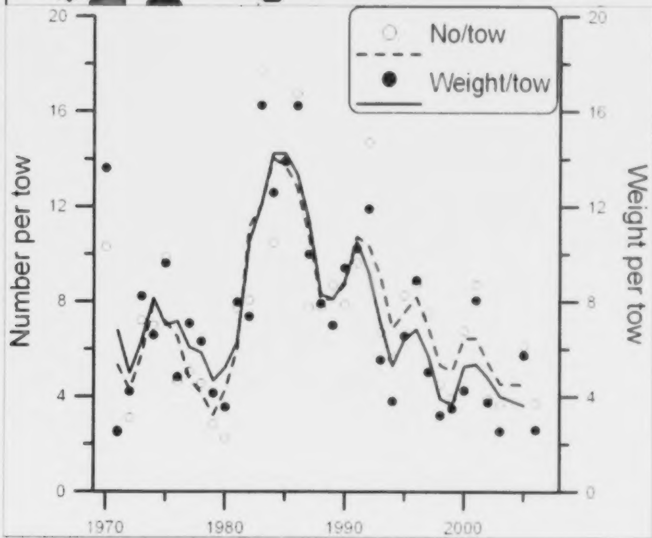
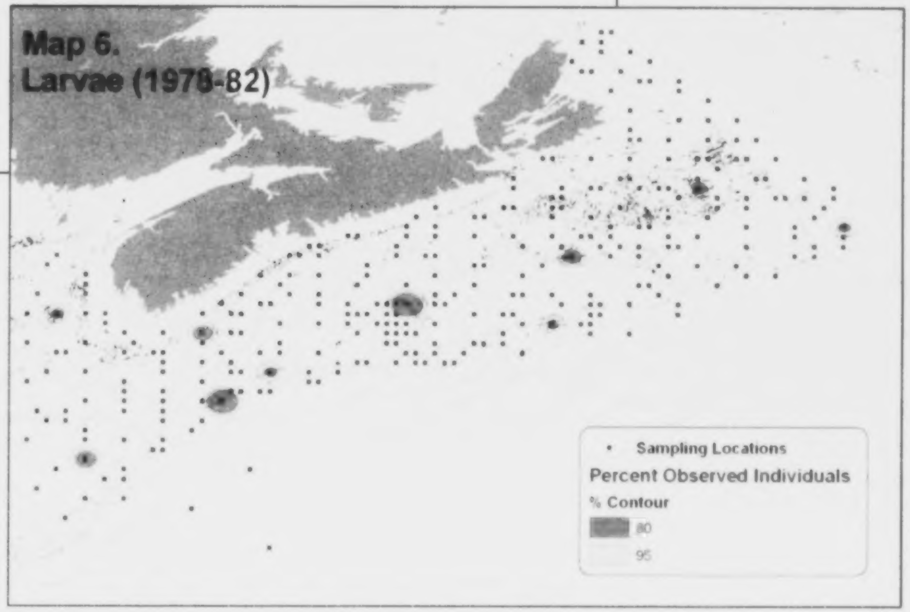
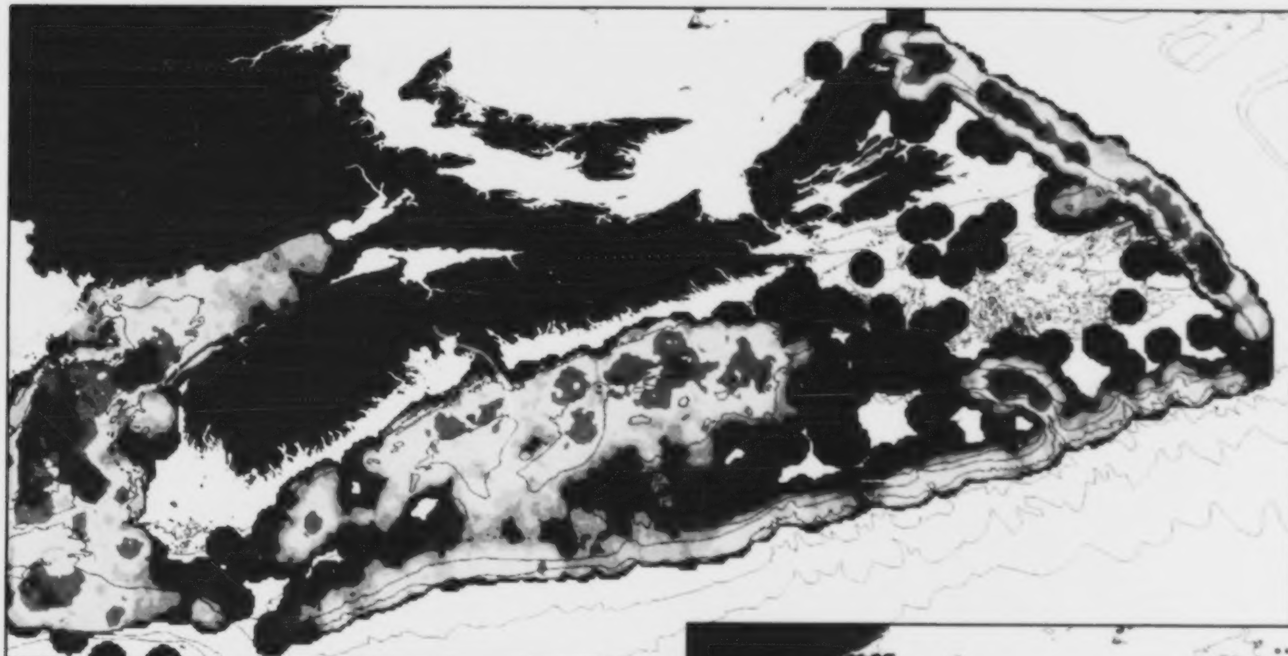
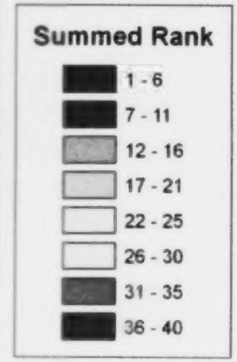


Figure 1. Population Trend



White Hake (*Urophycis tenuis*)





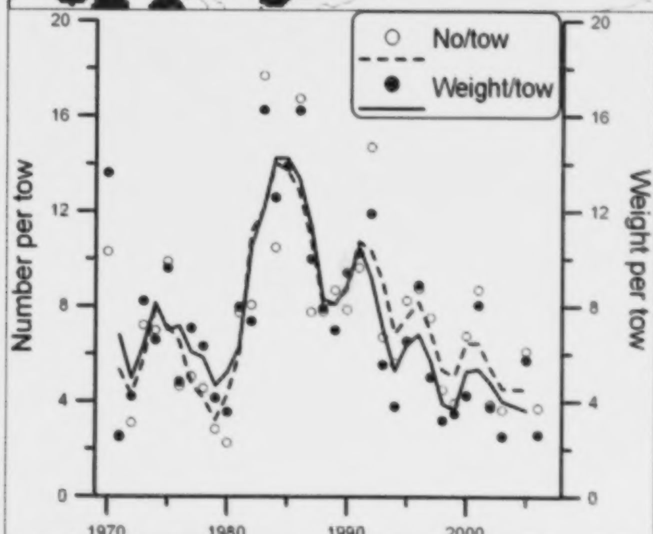
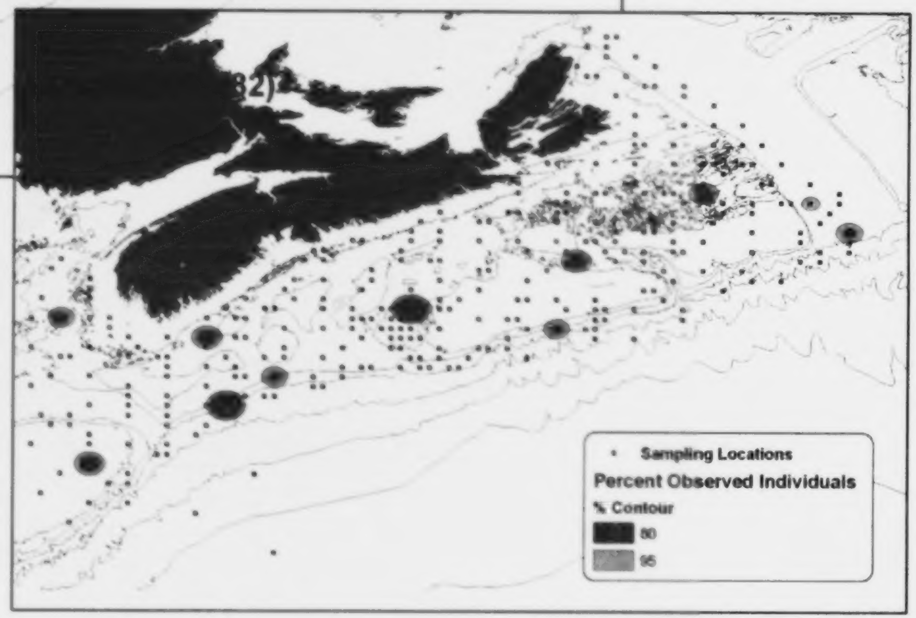
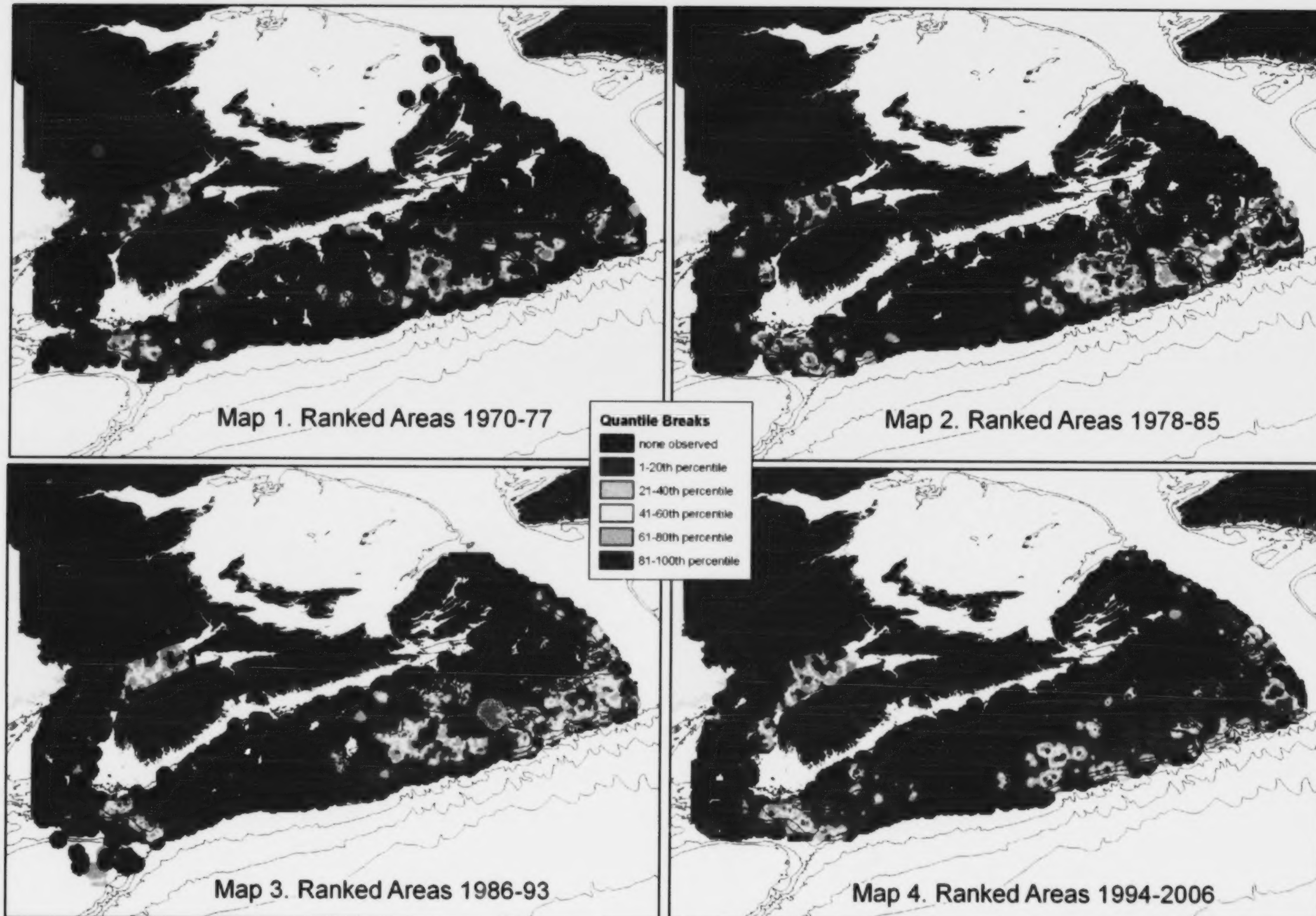


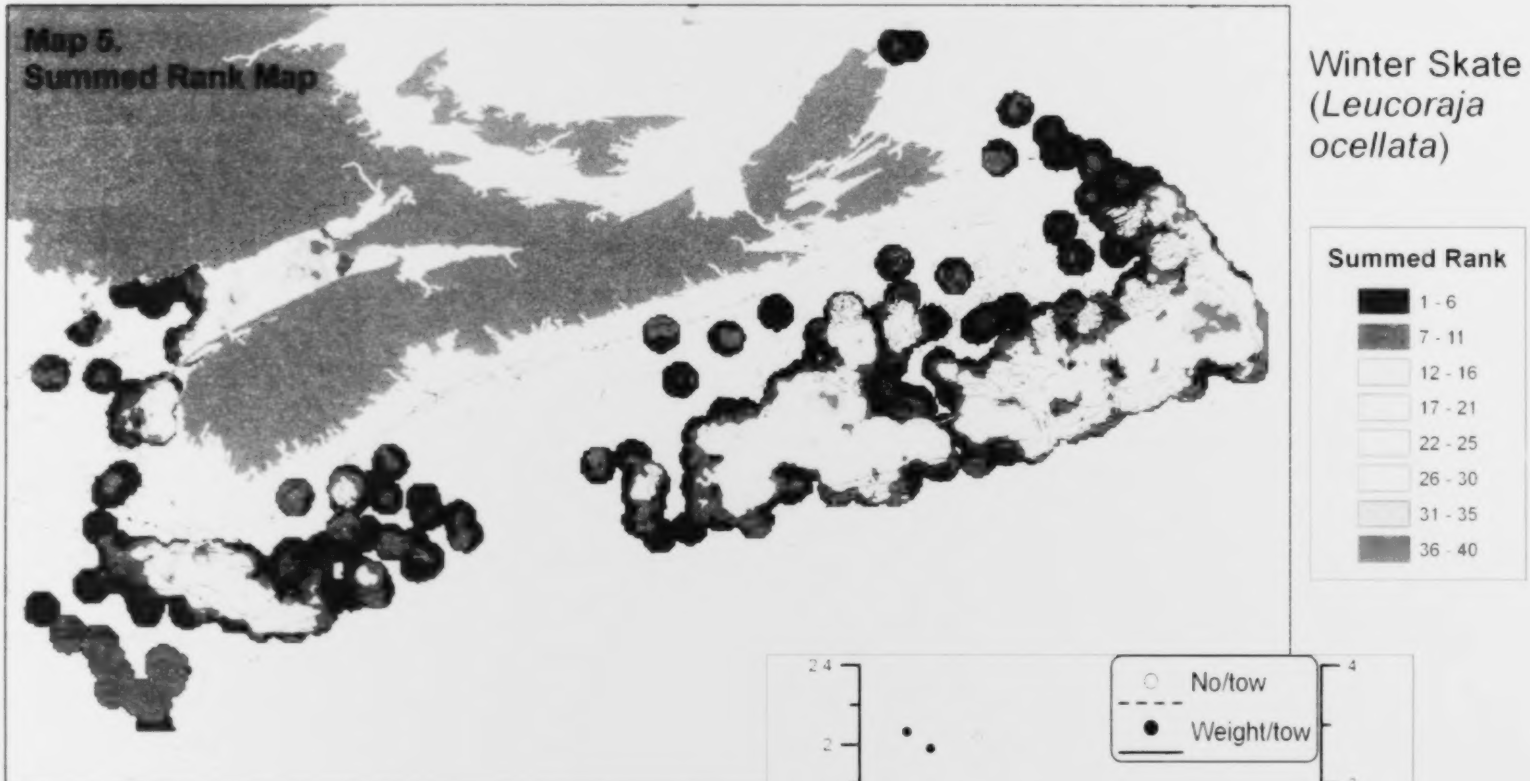
Figure 1. Population Trend



Winter Skate (*Leucoraja ocellata*)



Winter Skate (*Leucoraja ocellata*)



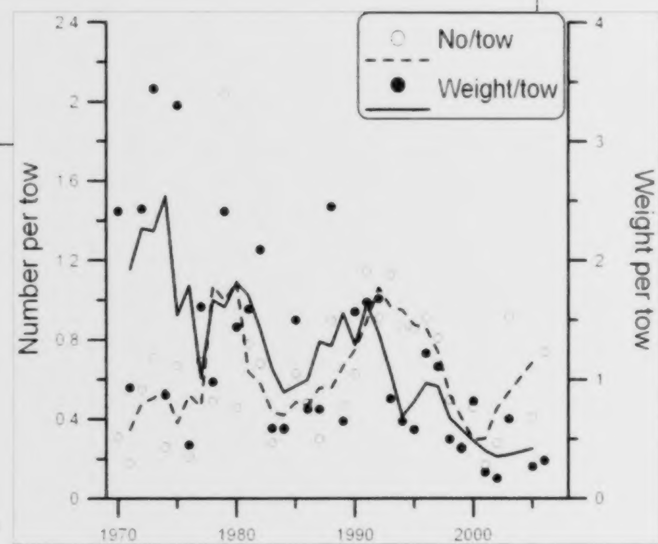
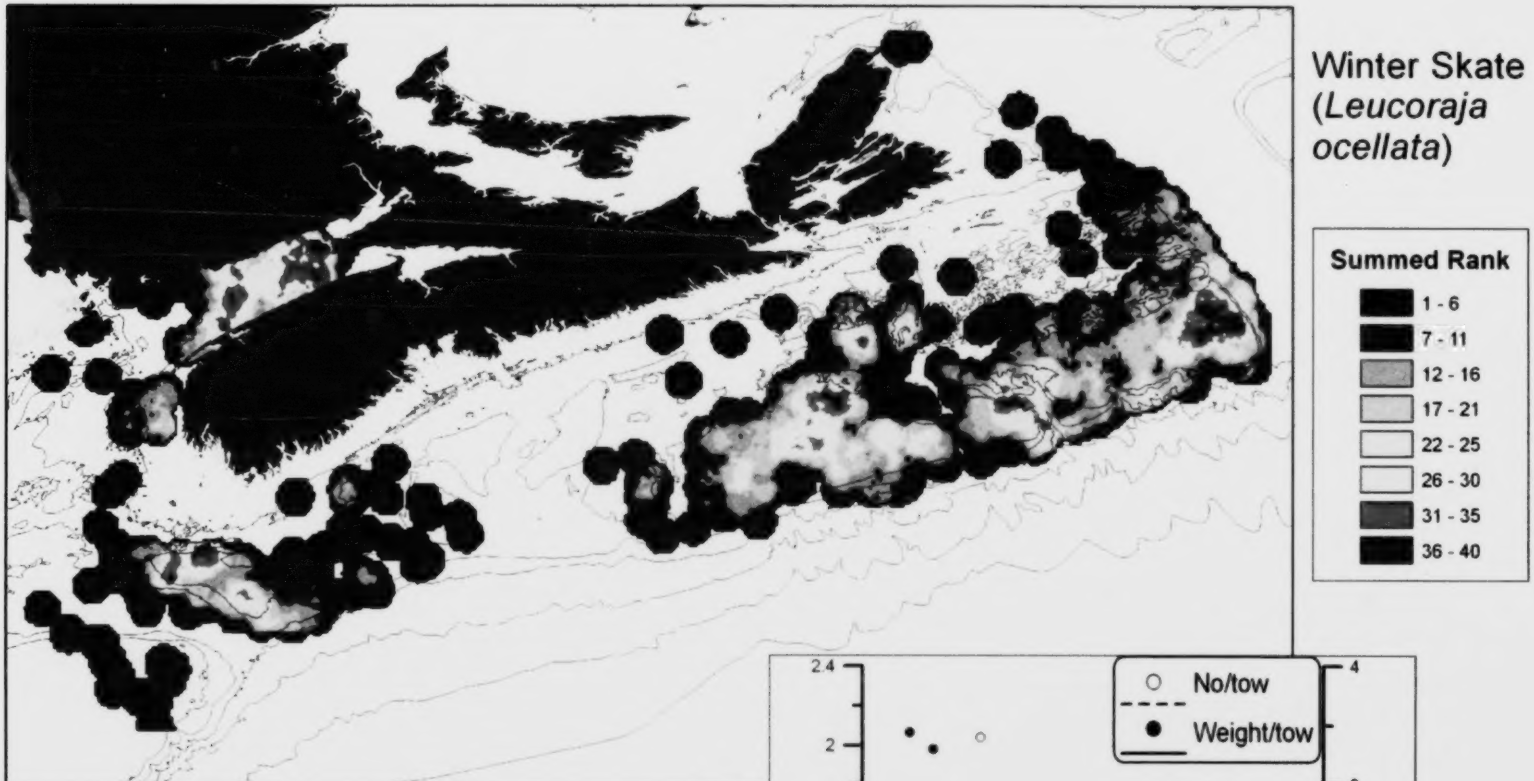


Figure 1. Population Trend

Winter Skate (*Leucoraja ocellata*)



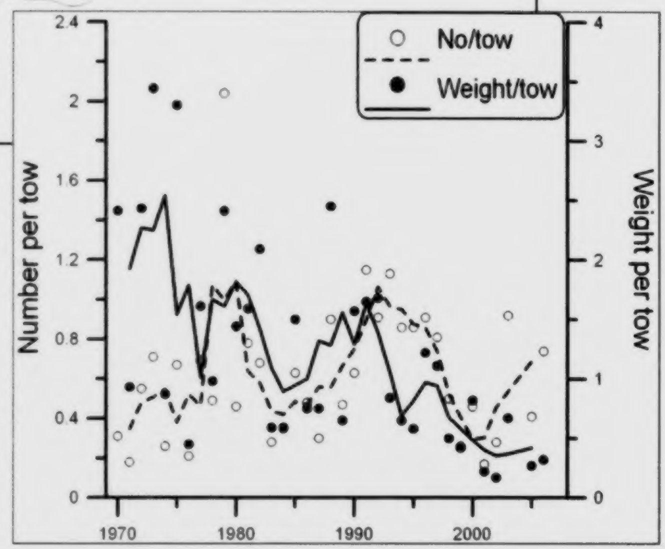


Figure 1. Population Trend

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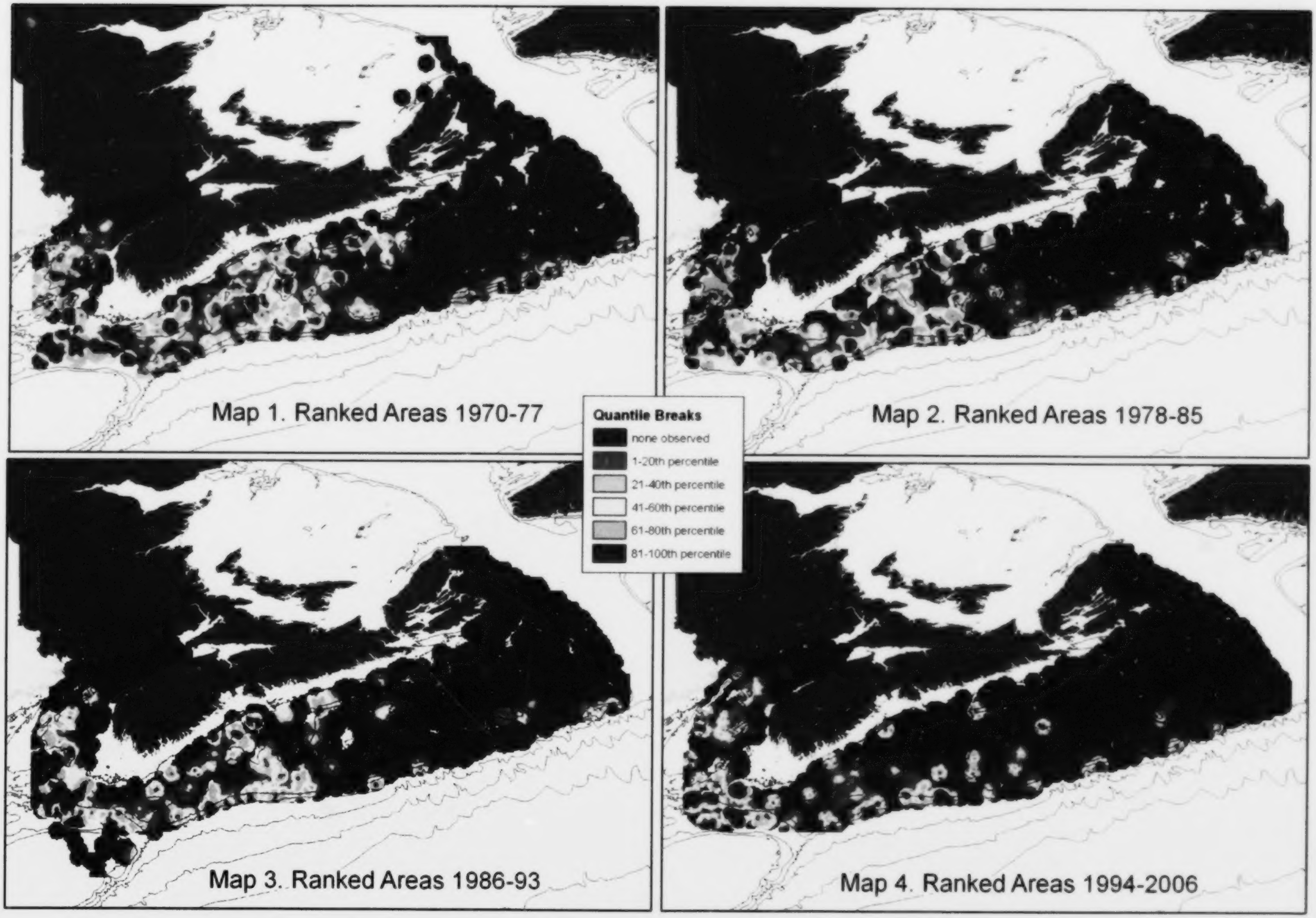
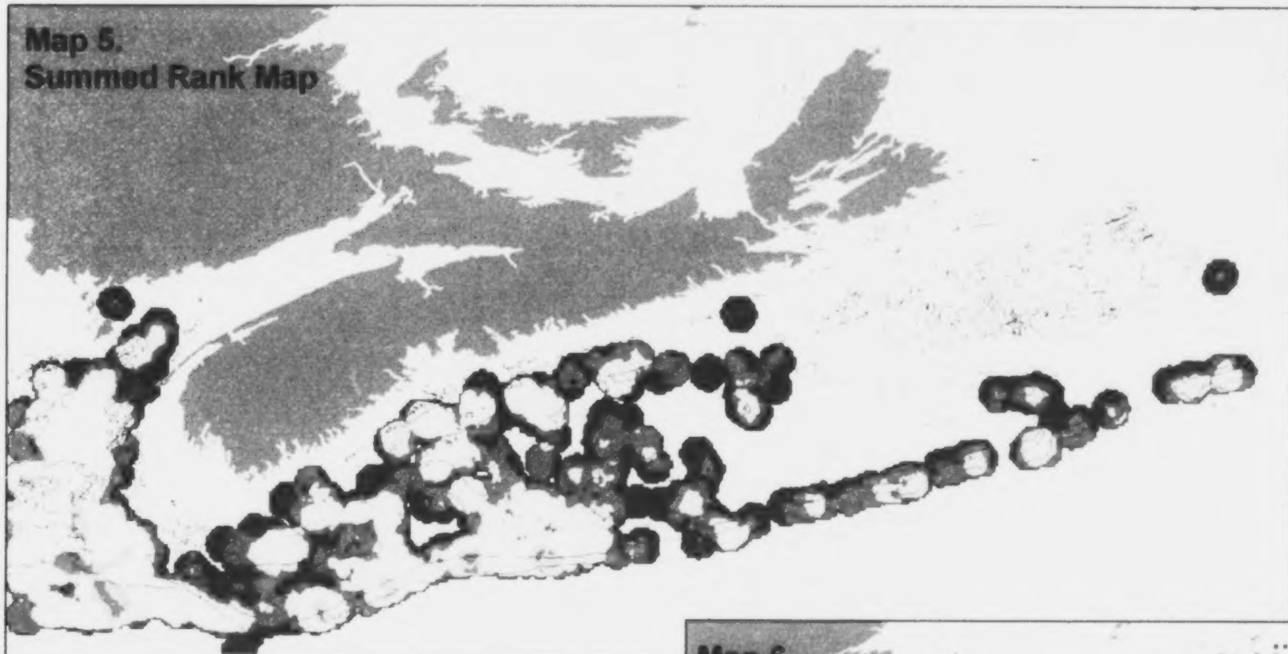
3.3 Depleted or Rare Species

The results of our evaluation of areas of persistently high ranking biomass and population trends can be found on the following pages for these species identified as depleted on the Scotian Shelf: Cusk (*Brosme brosme*); Northern Wolffish*(Anarhichas denticulatus)* Spotted Wolffish (*Anarhichas minor*); and Atlantic Wolffish (*Anarhichas lupus*). Both Winter Skate (*Leucoraja ocellata*) and Atlantic Cod (*Gadus morhua*), are identified as depleted but are also influential predators. The maps and population trends for these two species are found in section 3.2 of this report.

Cusk (*Brosme brosme*)



Cusk (*Brosme brosme*)



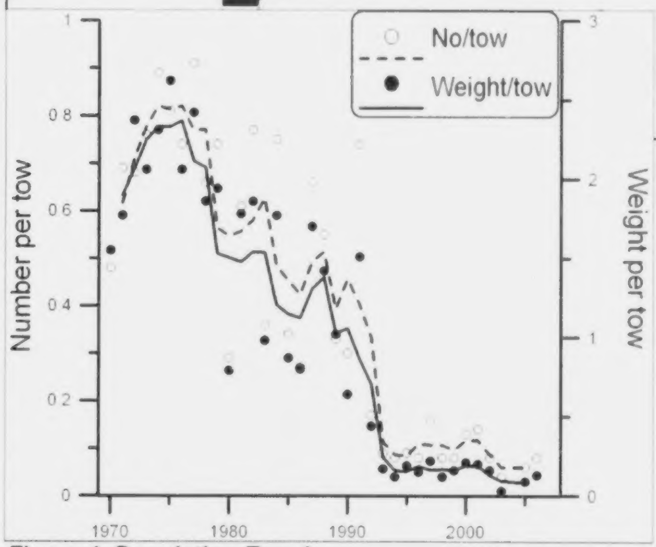
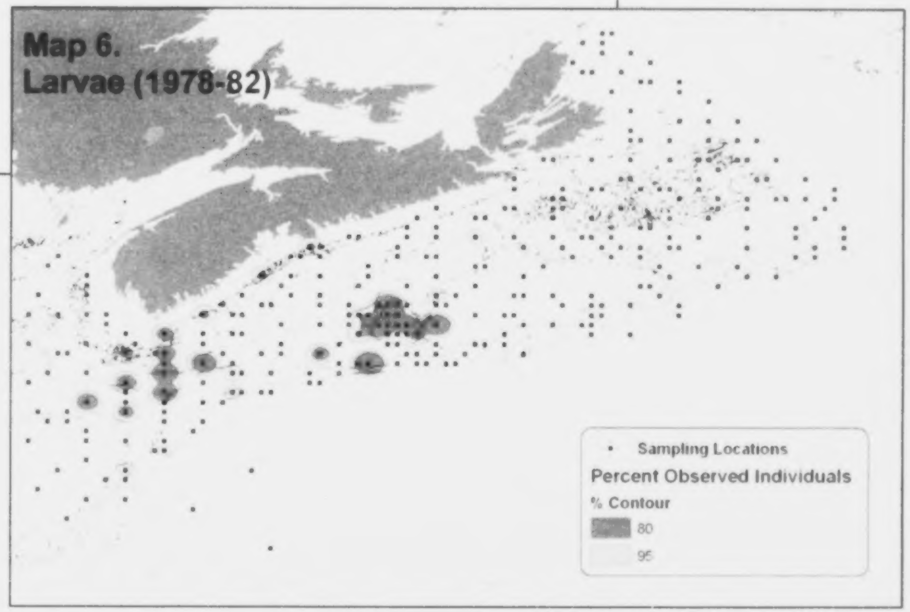
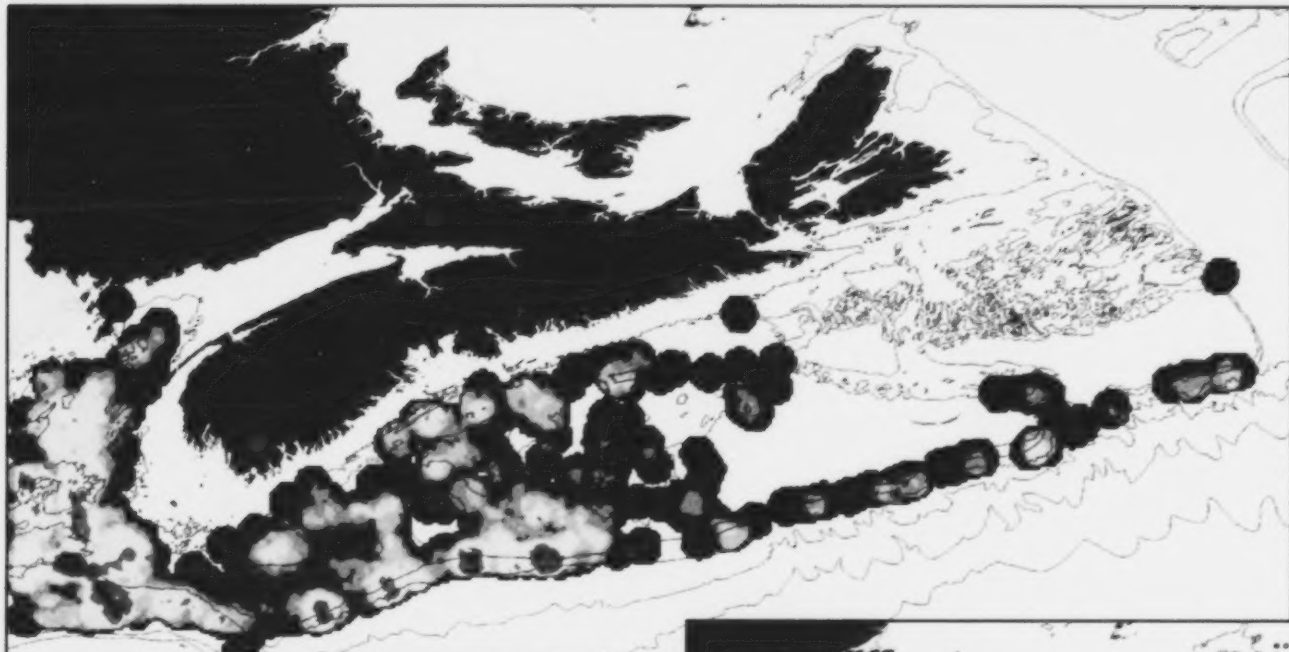
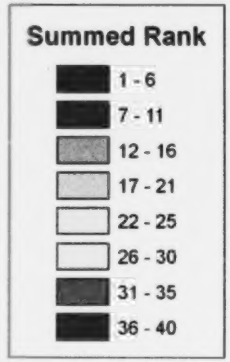


Figure 1. Population Trend



Cusk
(*Brosme brosme*)





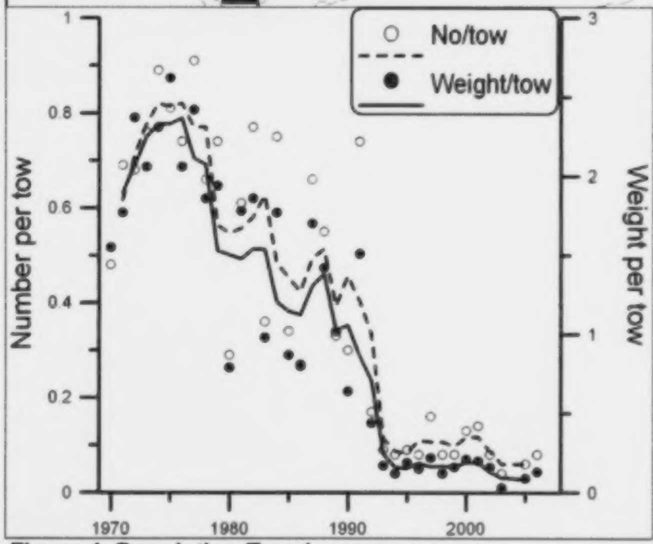
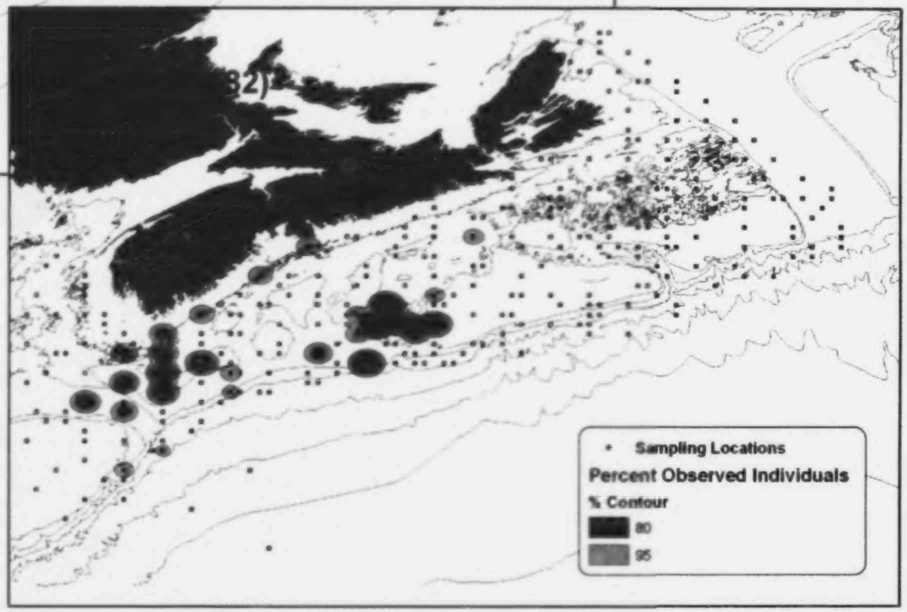
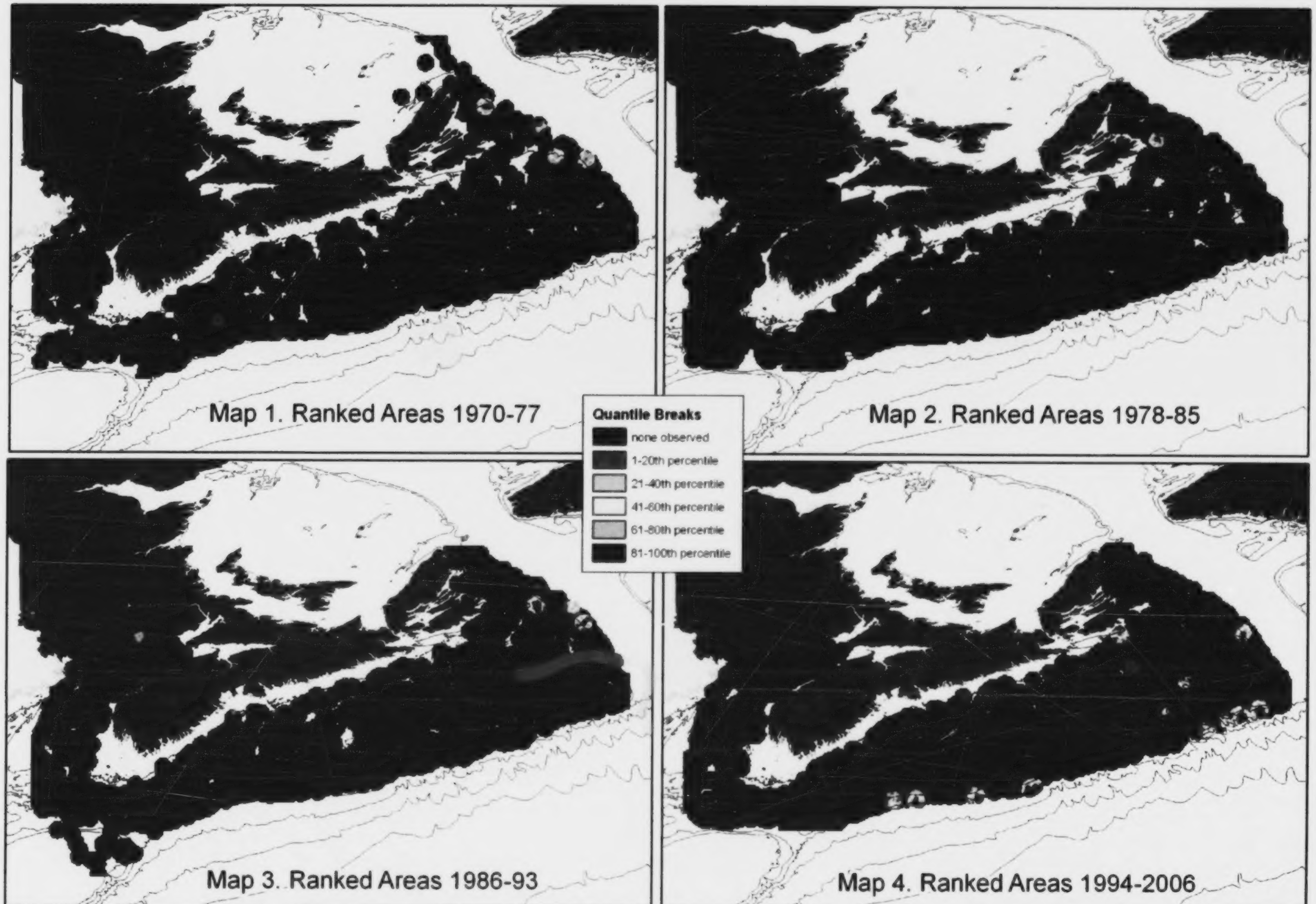


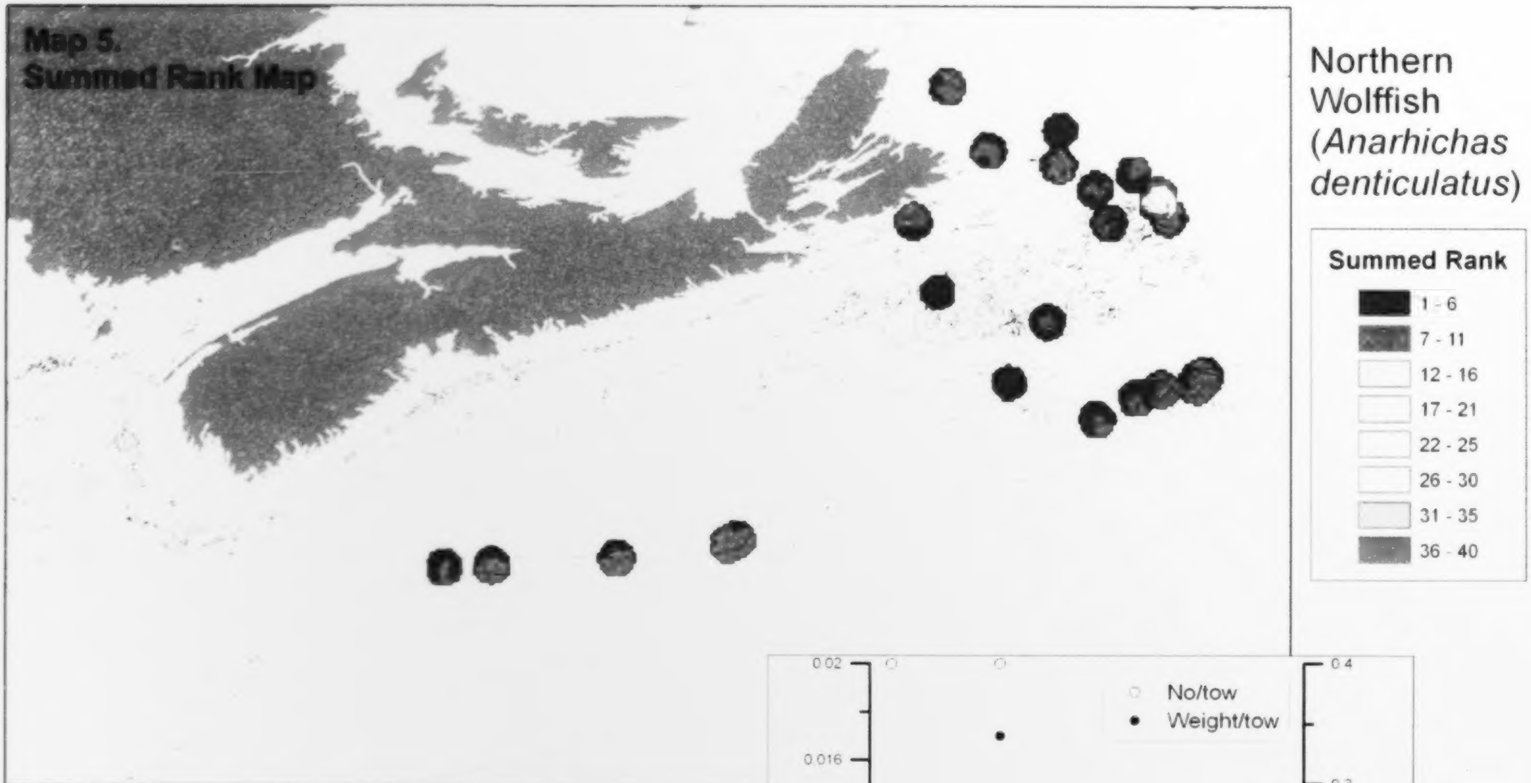
Figure 1. Population Trend



Northern Wolffish (*Anarhicus denticulatus*)



Northern Wolffish (*Anarhichas denticulatus*)



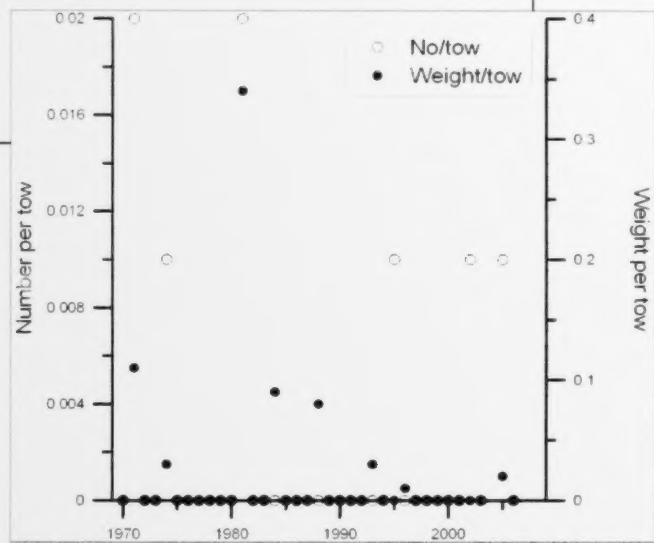
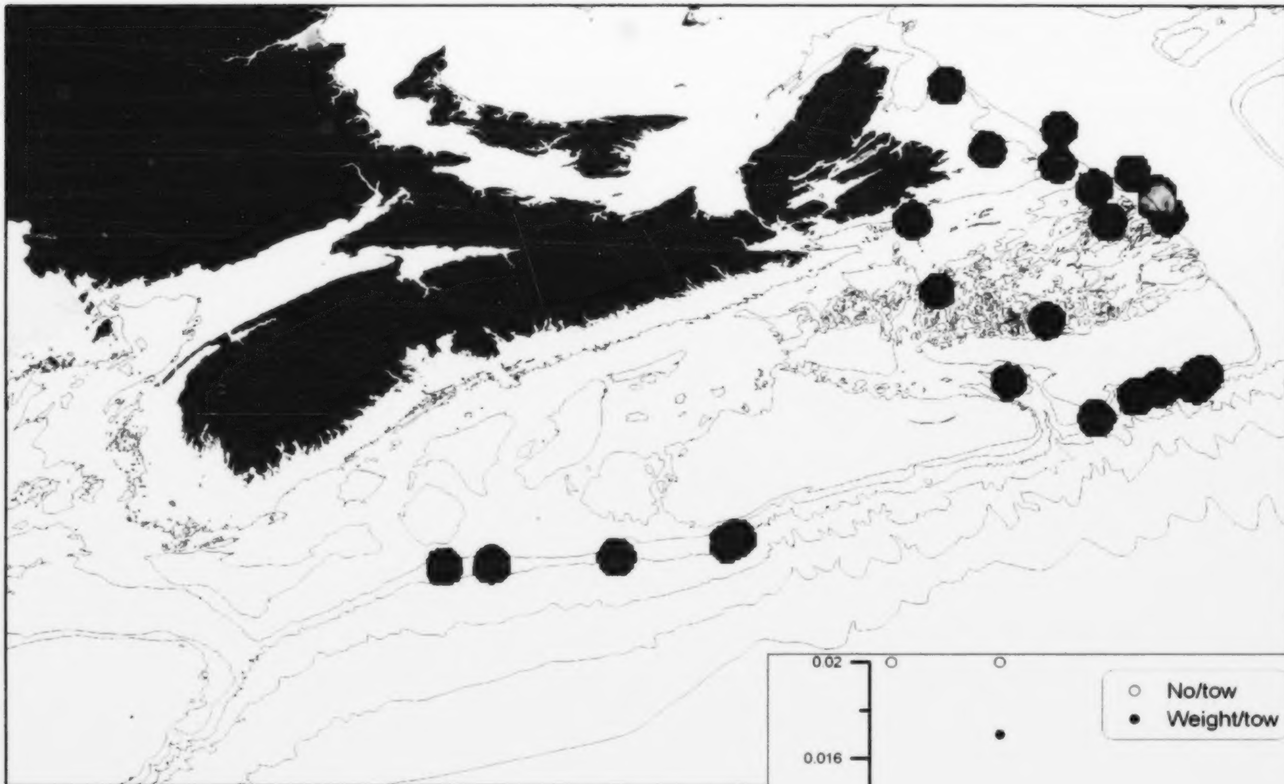


Figure 1. Population Trend

Northern Wolffish (*Anarhichas denticulatus*)



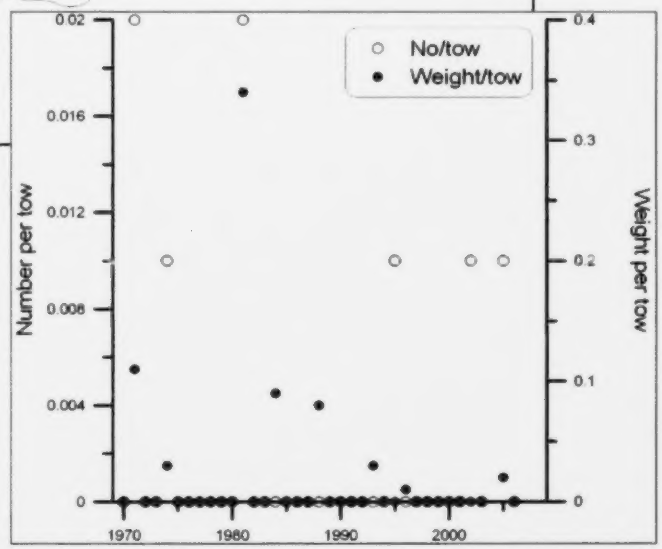
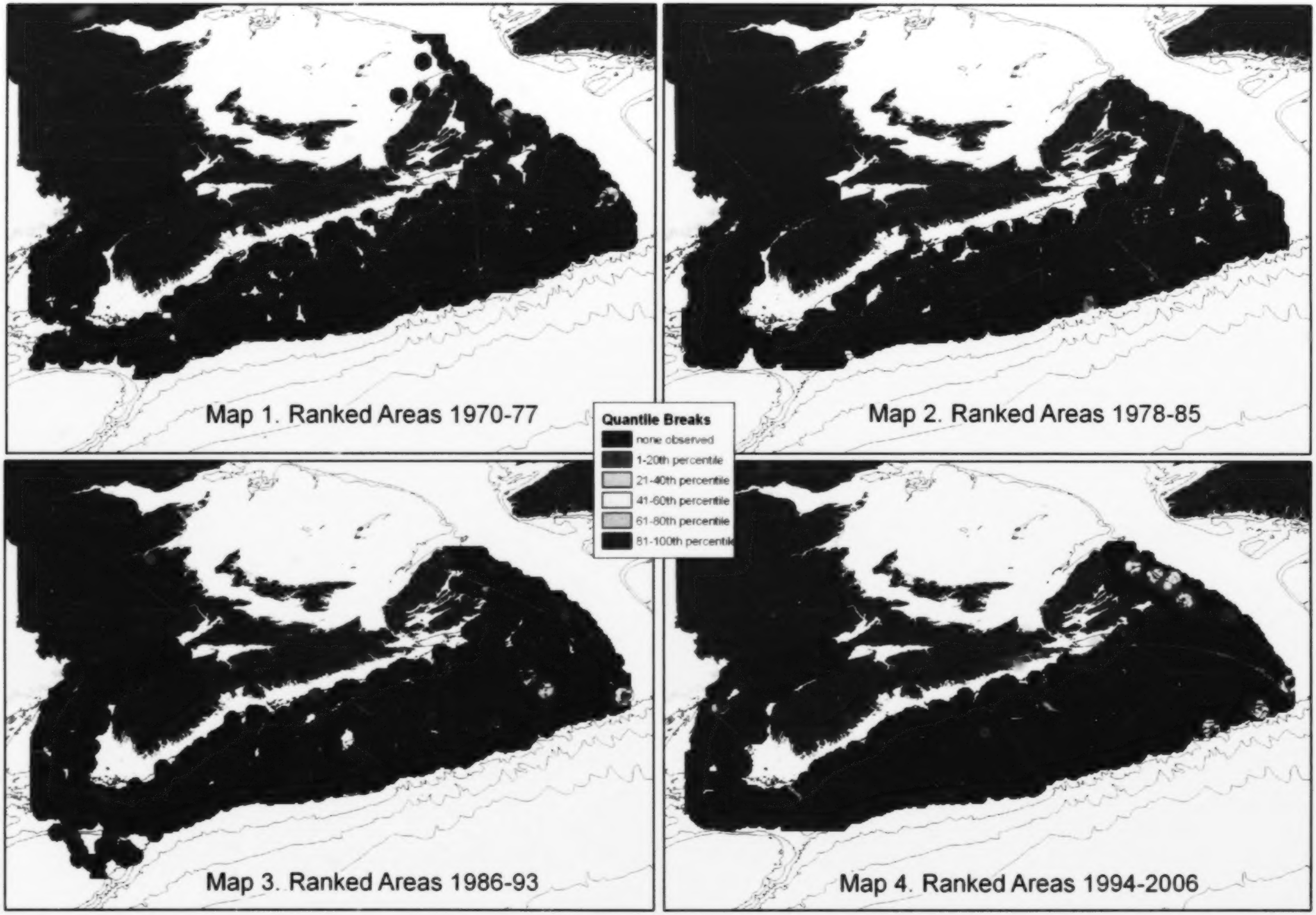
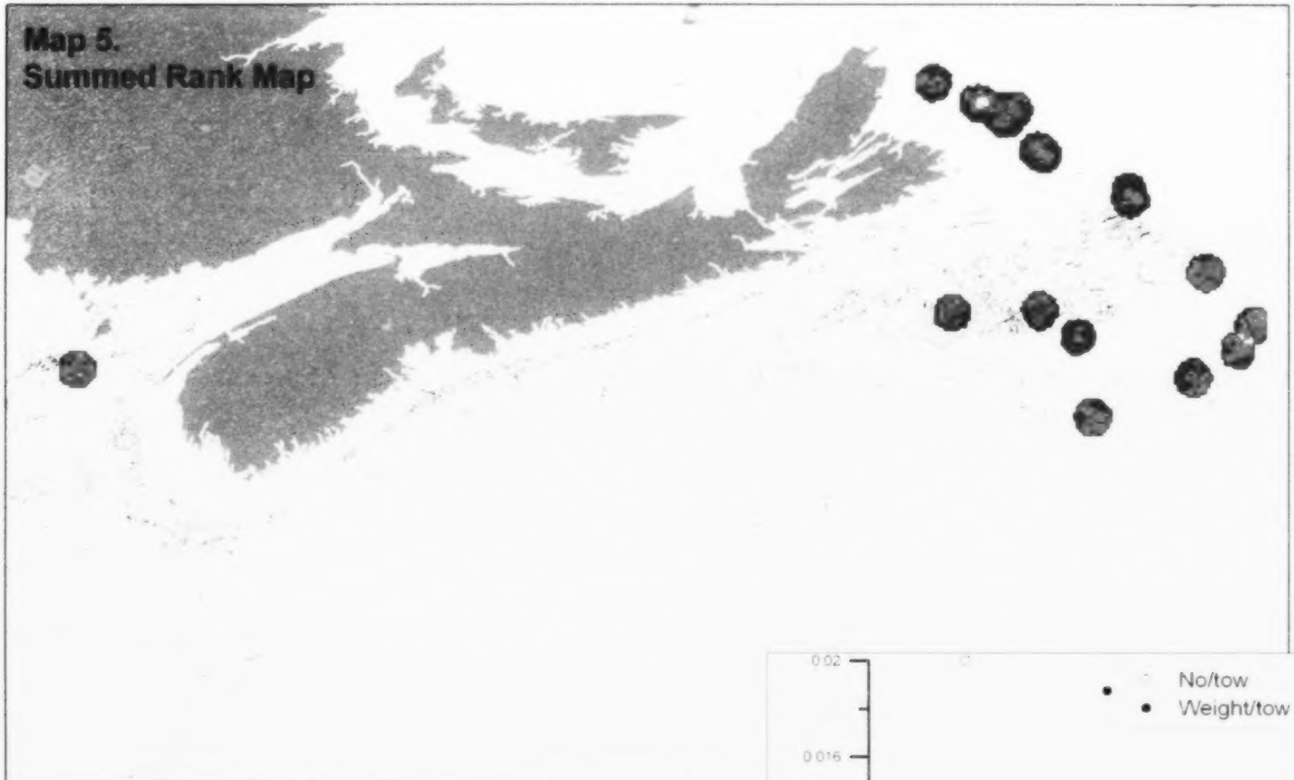


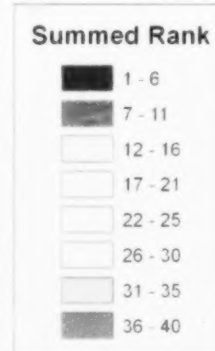
Figure 1. Population Trend

Spotted Wolffish (*Anarhicus minor*)



Spotted Wolffish (*Anarhichas minor*)





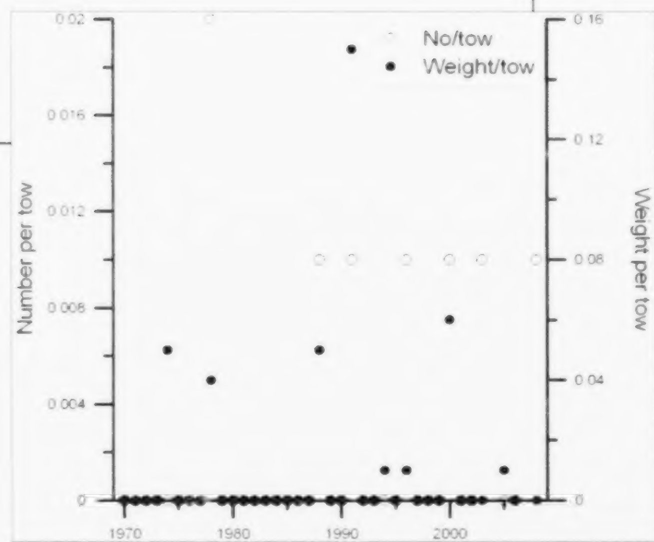
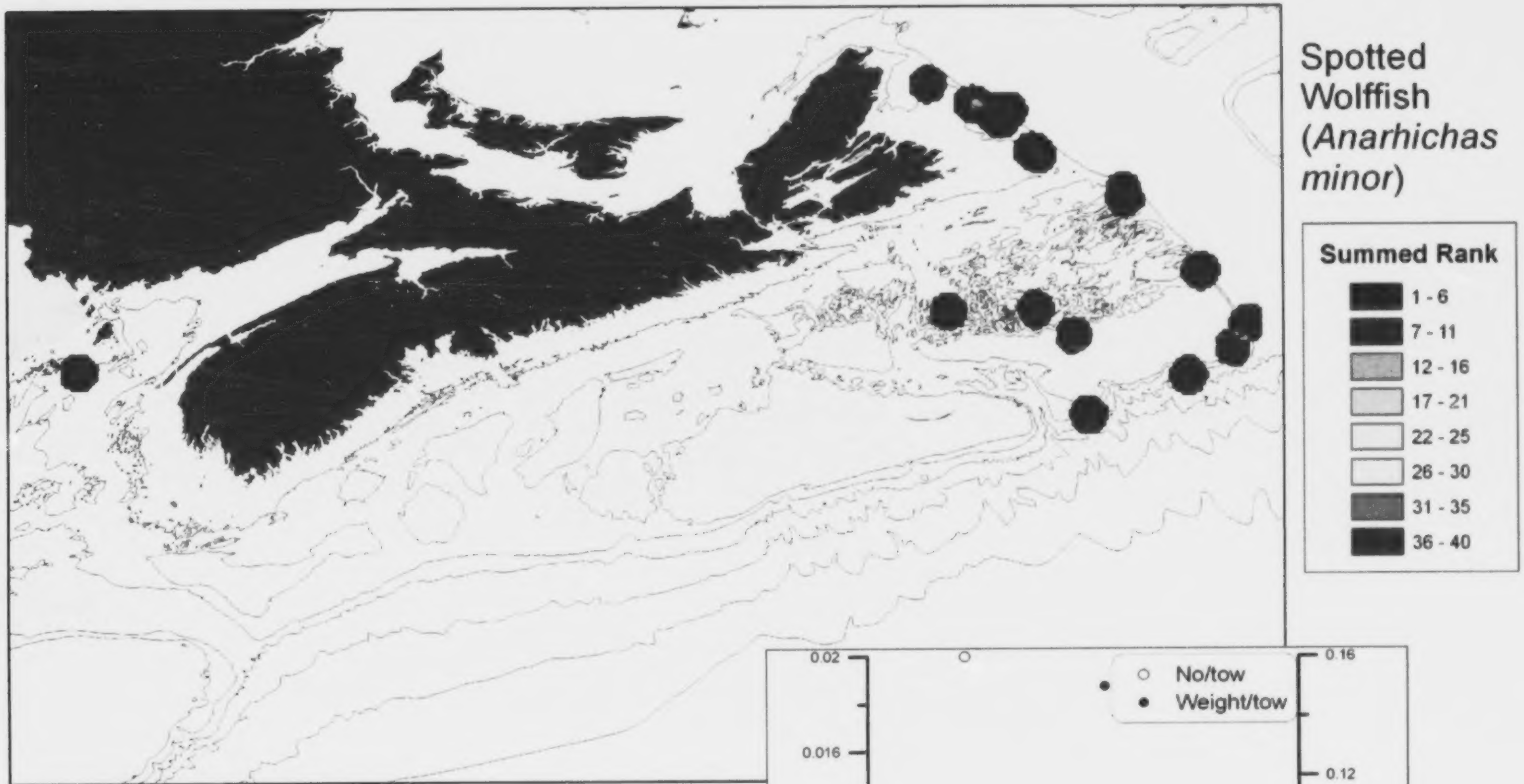


Figure 1. Population Trend



Spotted
Wolffish
(*Anarhichas
minor*)

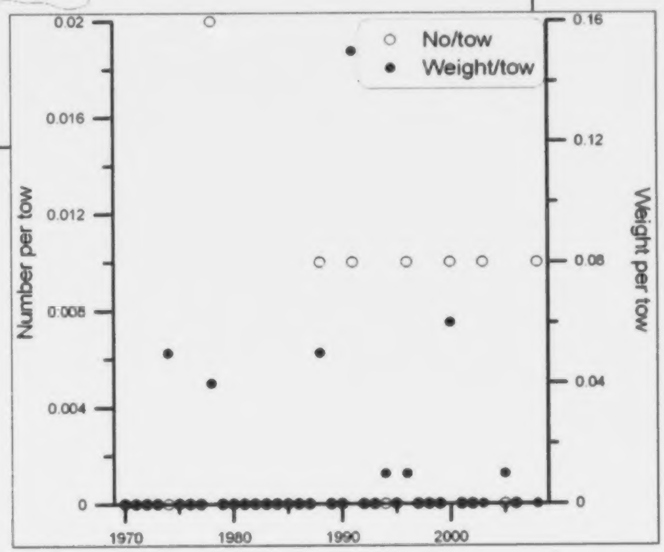
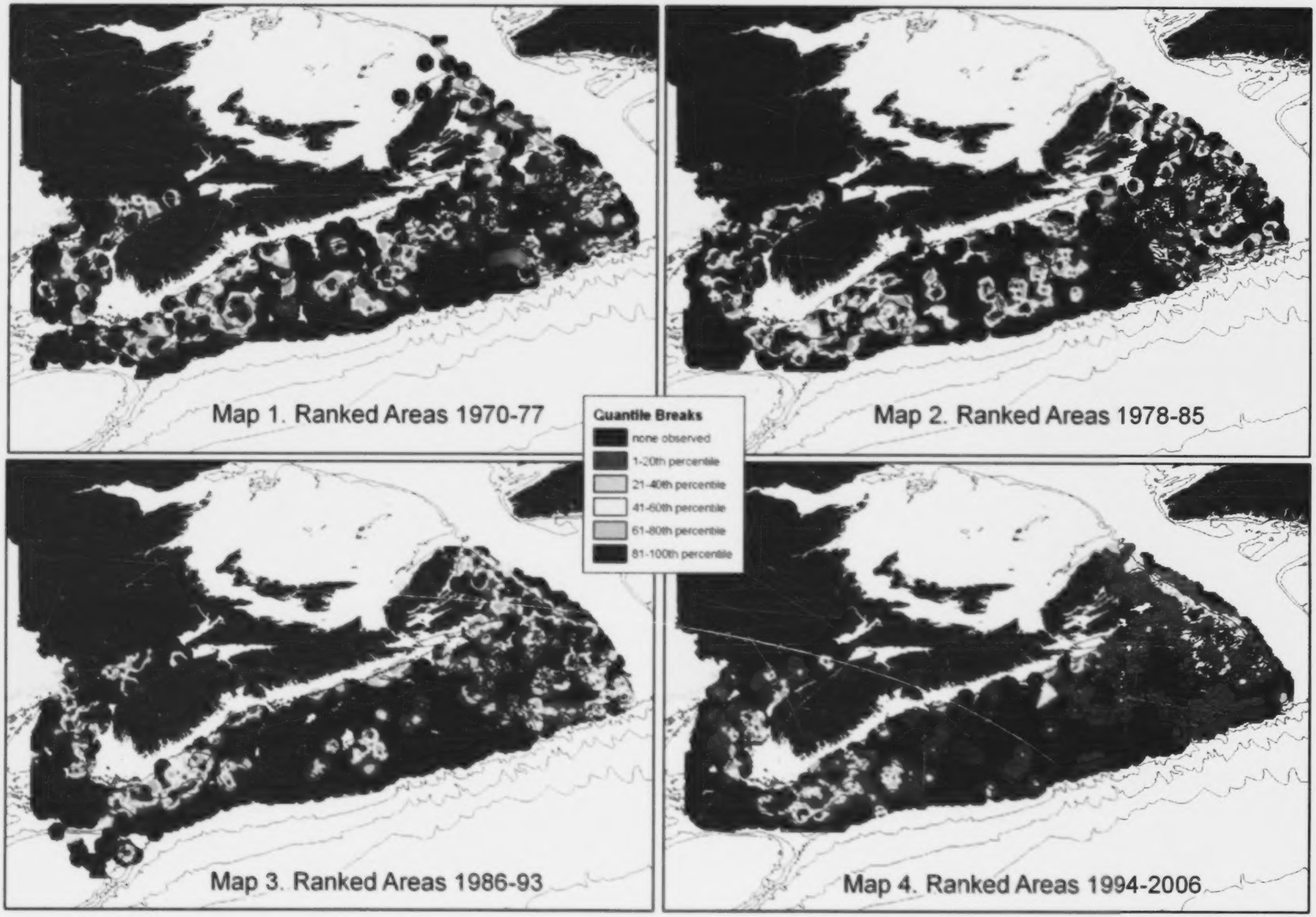
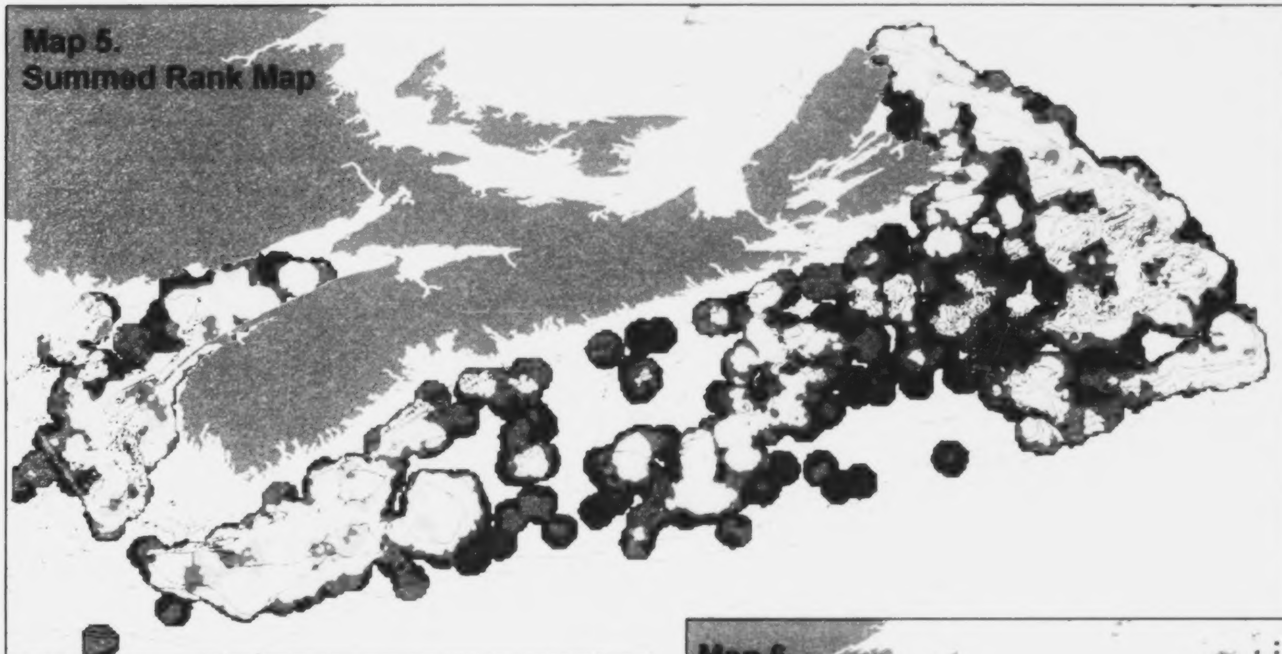


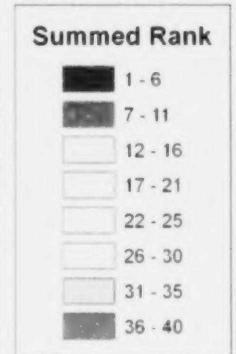
Figure 1. Population Trend

Atlantic Wolffish (*Anarhicus lupus*)



Atlantic Wolffish (*Anarhichas lupus*)





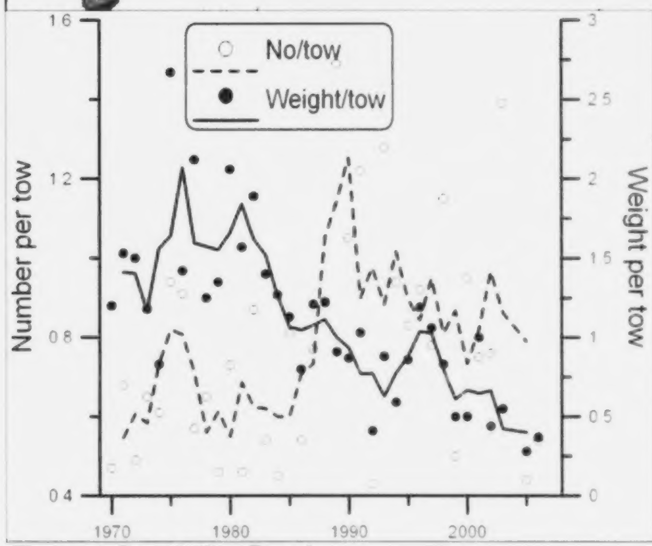
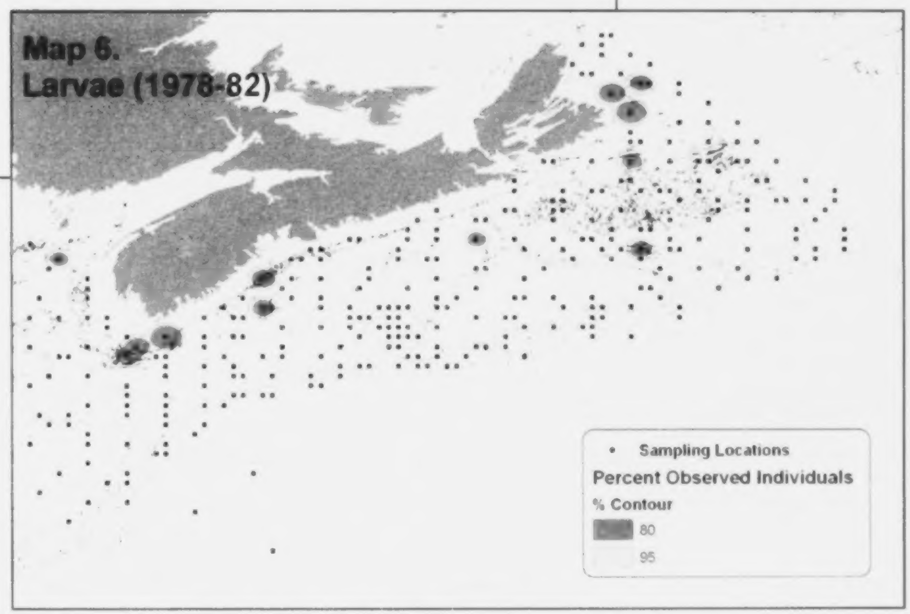


Figure 1. Population Trend



Atlantic Wolffish (*Anarhichas lupus*)

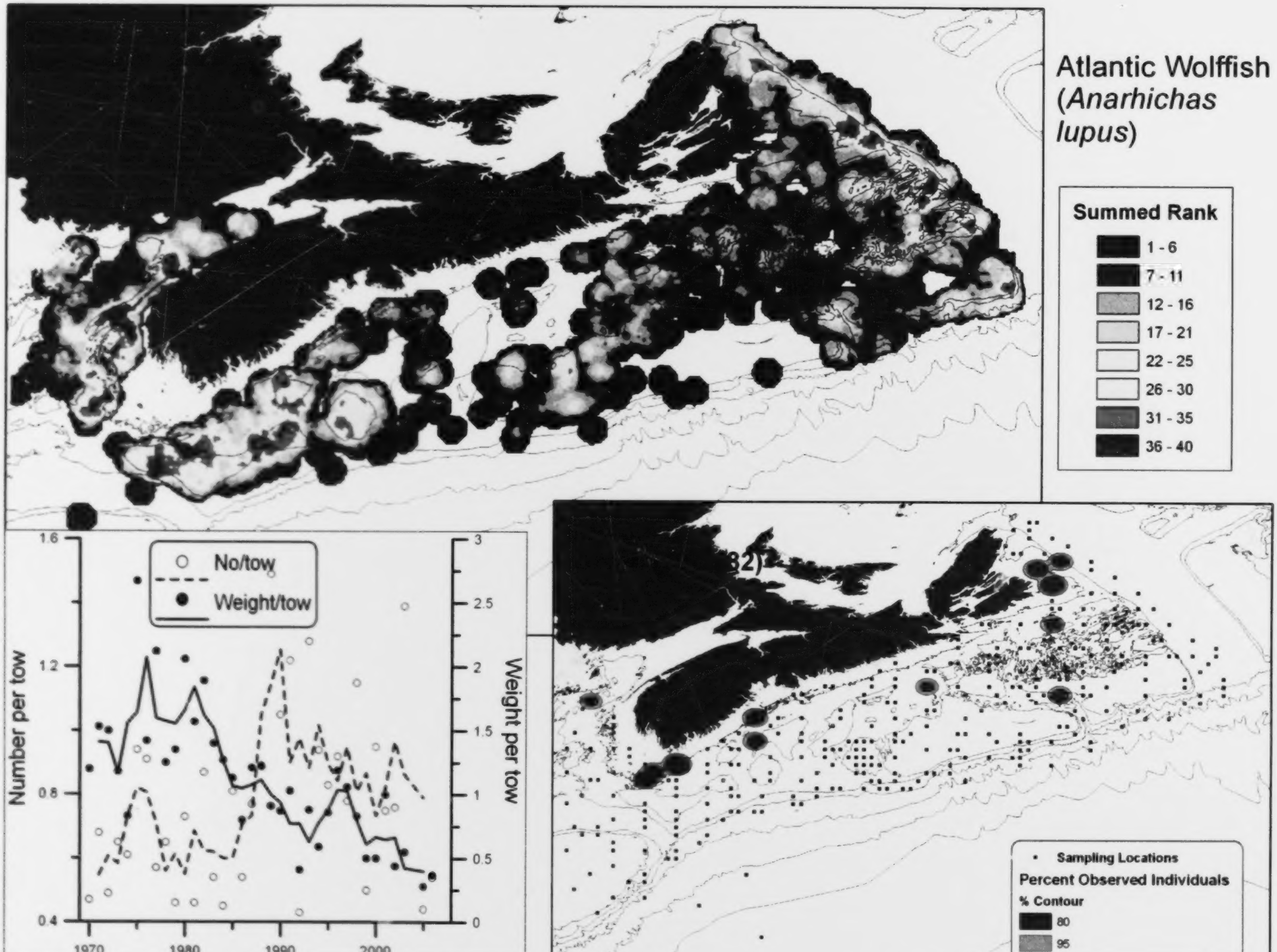


Figure 1. Population Trend

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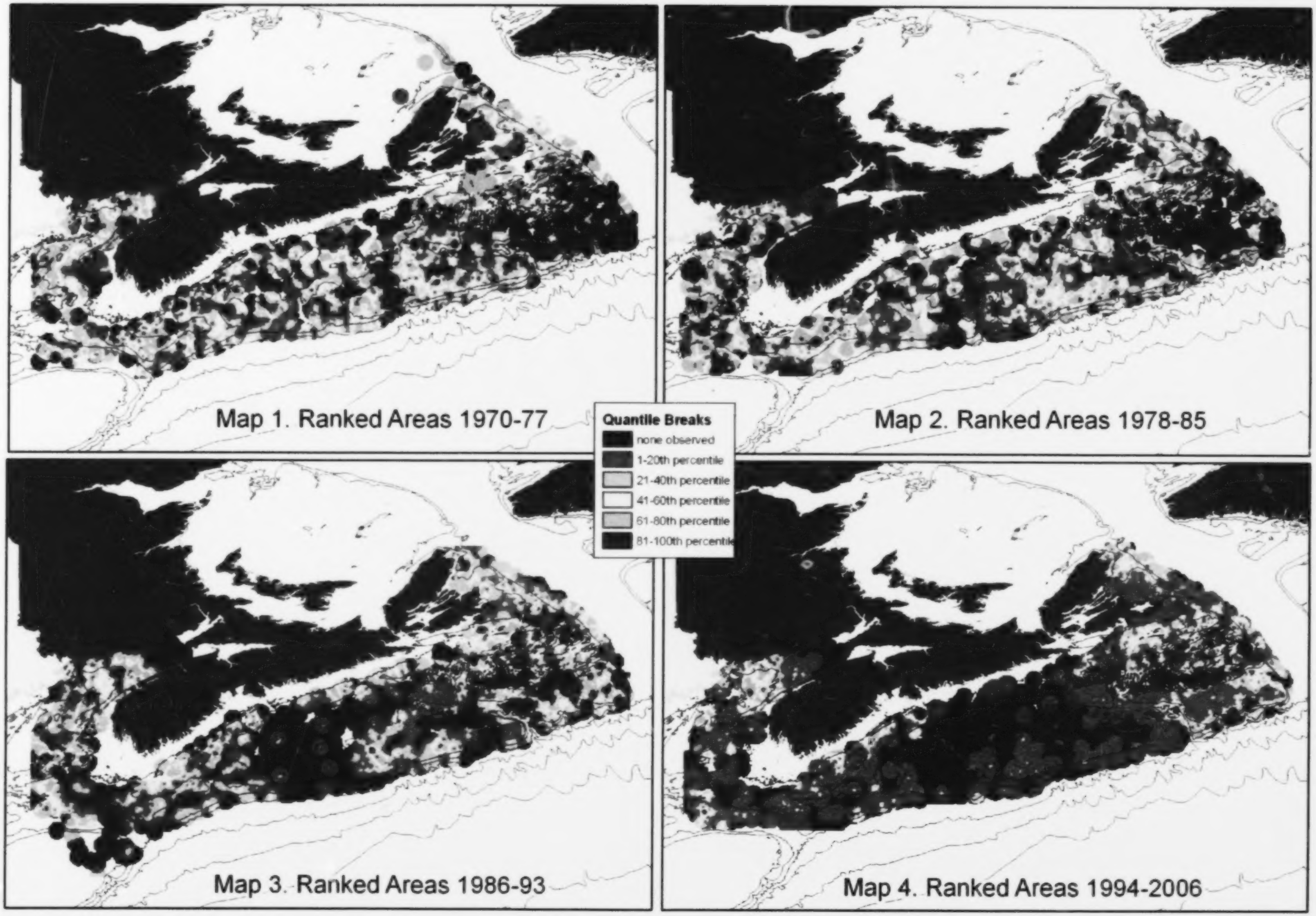
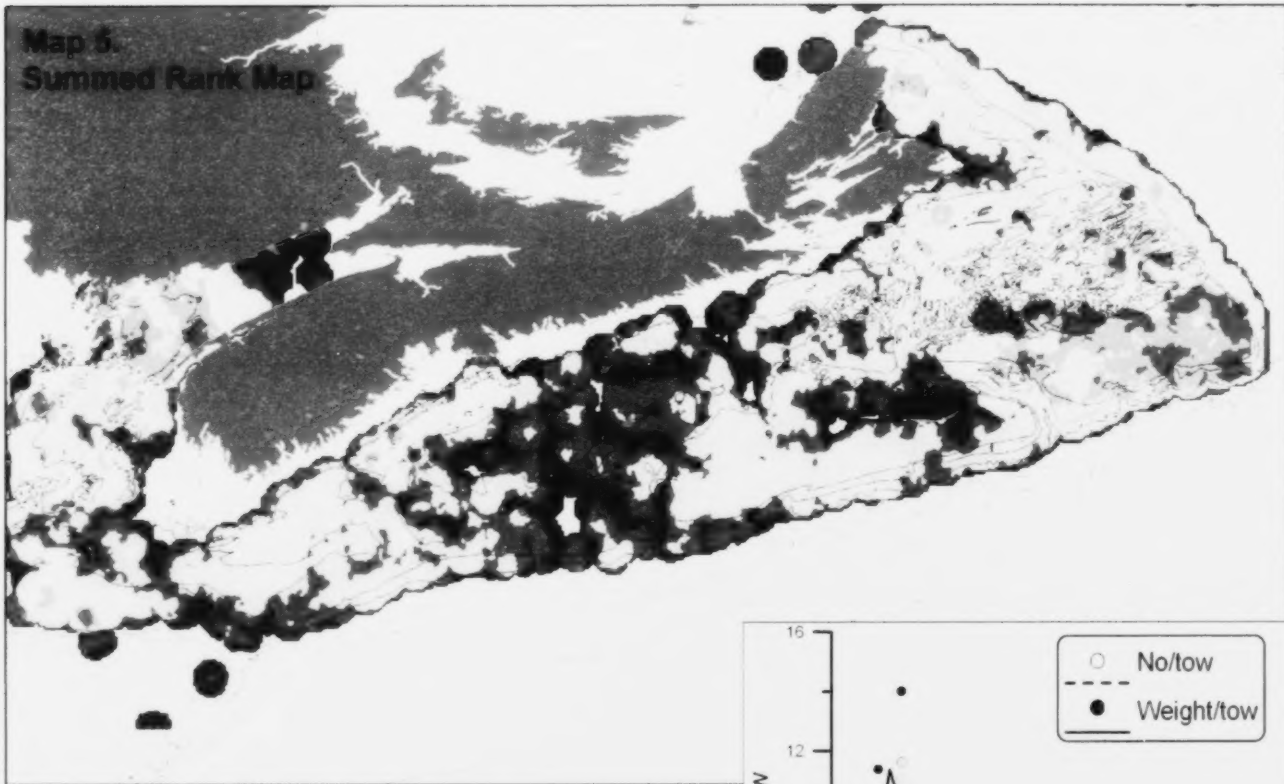
3.4 Other Dominant Species Observed in the Summer Trawl Surveys

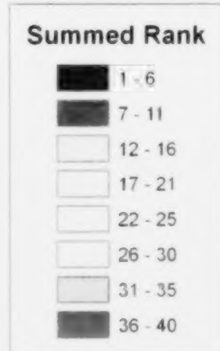
The results of our evaluation of areas of persistently high ranking biomass and the population trends can be found on the following pages for species that have been observed to be dominant in the RV surveys (i.e., >10% occurrence in all trawl sets) but that weren't identified as ecologically significant species in any of the existing categories. These nine species are: Moustache/Mailed Sculpin *(Triglops murrayi)*; Thorny Skate (*Amblyraja radiata)*; Yellowtail Flounder *(Limanda ferruginea)*; Monkfish *(Lophius americanus)*; Sea Raven/Sea Sculpin *(Hemitripterus americanus)*; Ocean Pout *(Zoarces americanus)*; Blackback/Winter Flounder *(Pseudopleuronectes americanus)*; Altantic Argentine *(Argentina silus)*; Longfin Hake *(Phycis chesteri)*.

Thorny Skate (Amblyraja radiate)





Thorny Skate (*Amblyraja radiate*)



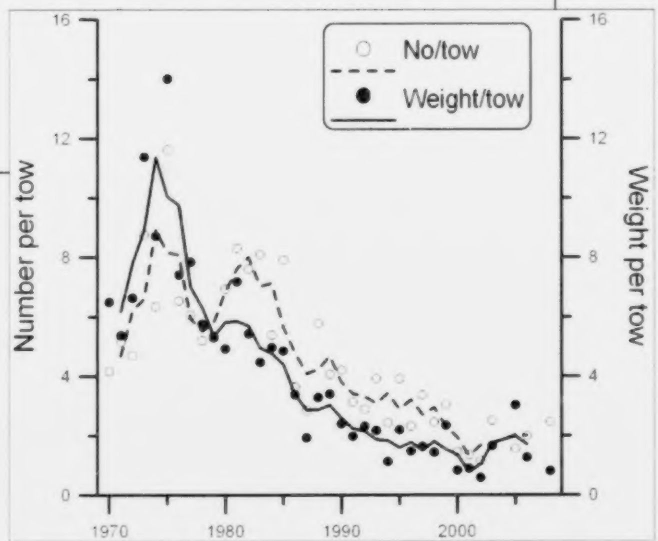
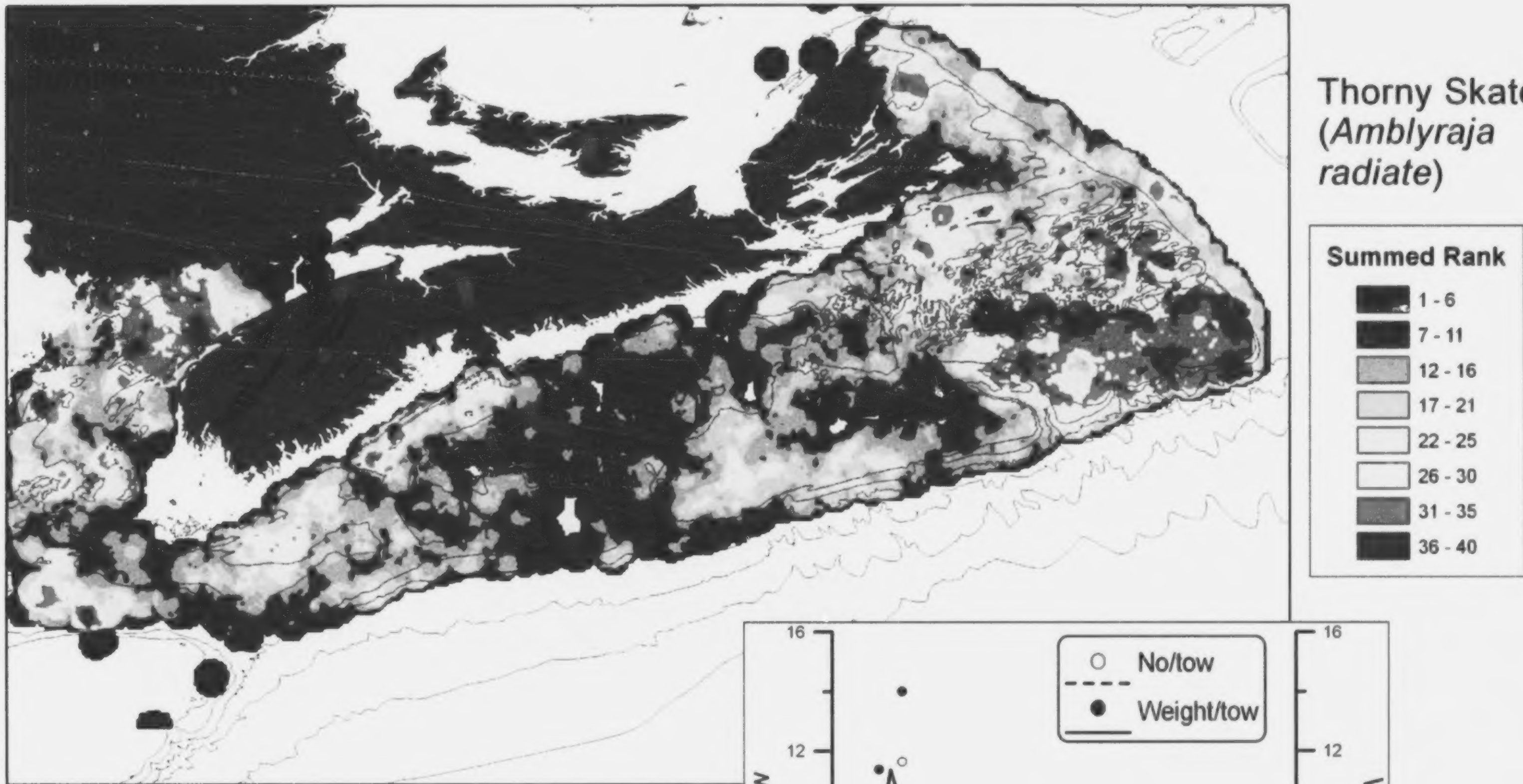


Figure 1. Population Trend

Thorny Skate (*Amblyraja radiate*)



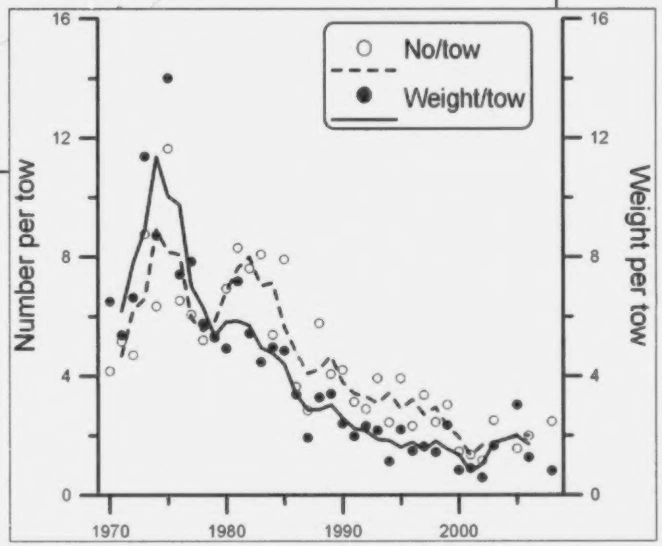
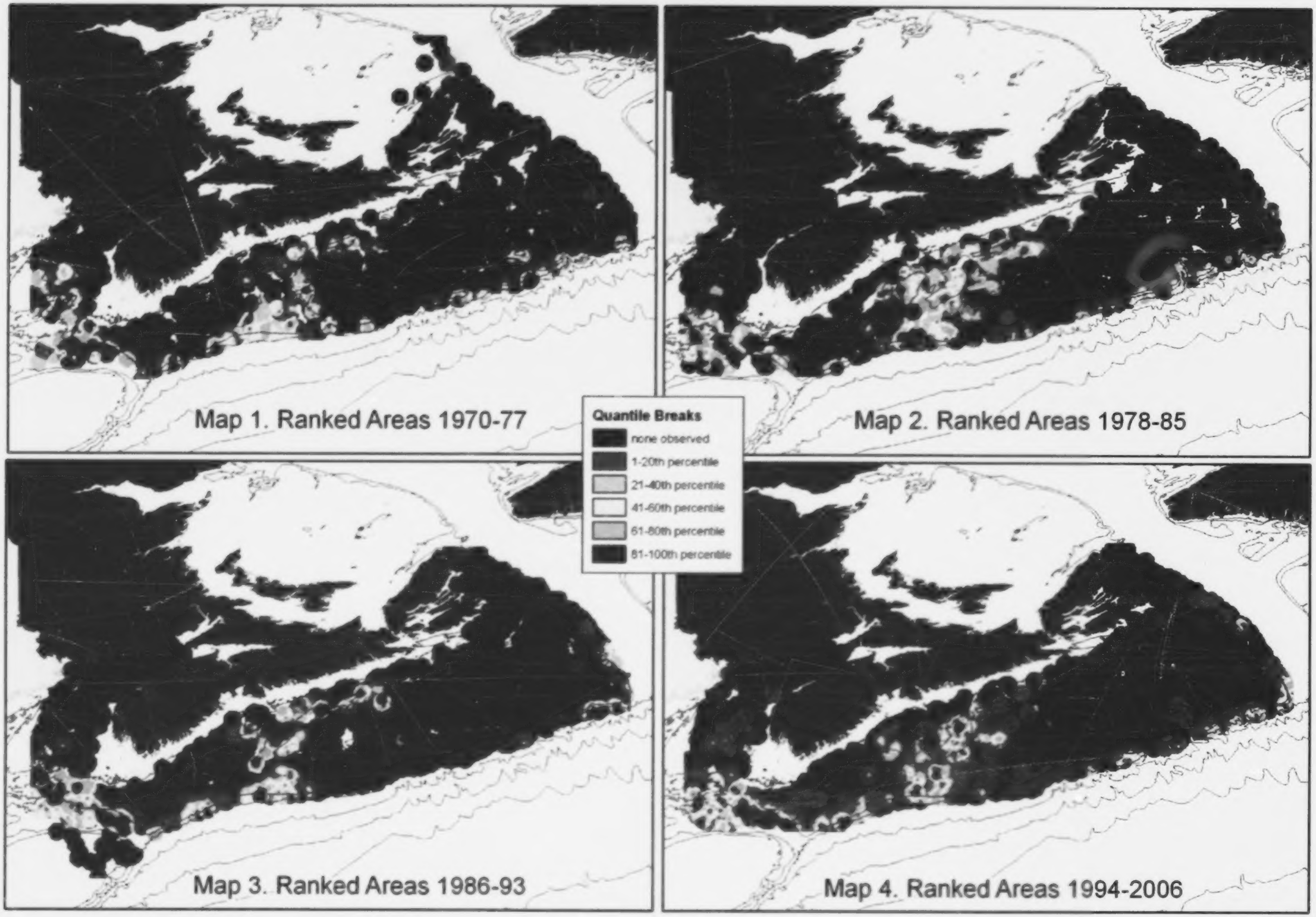
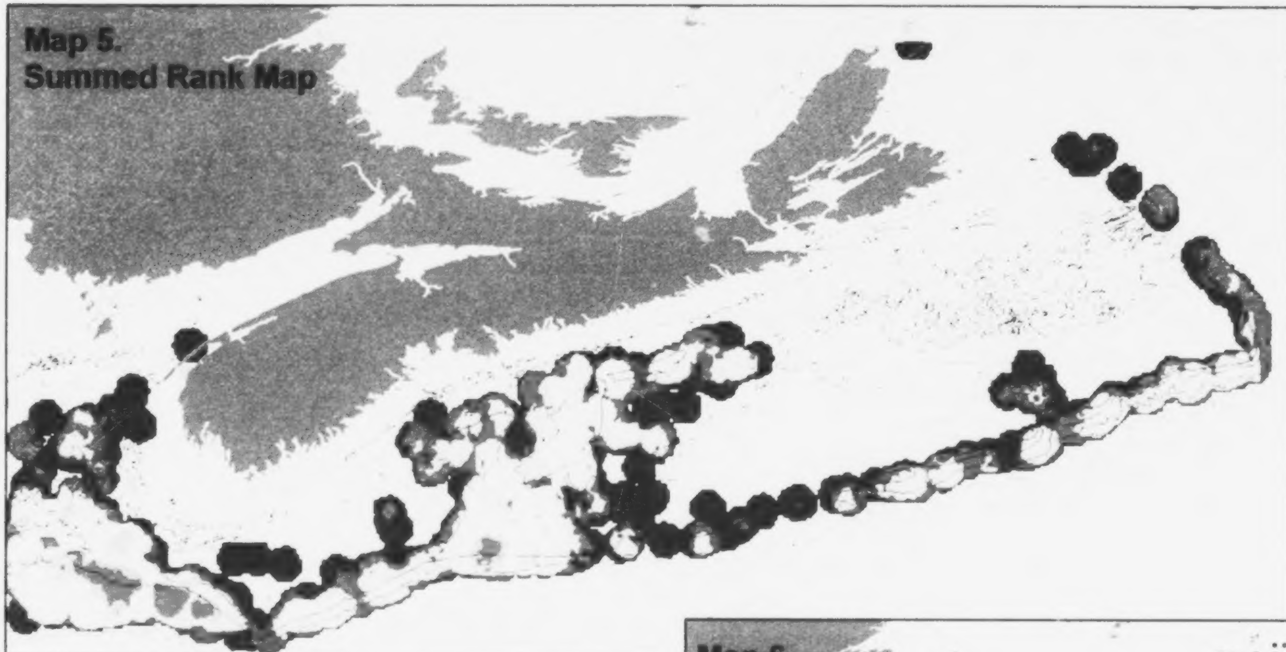


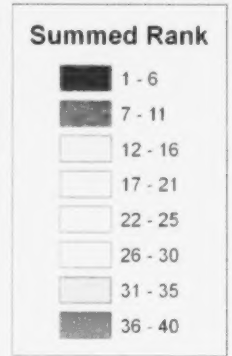
Figure 1. Population Trend

Atlantic argentine (*Argentina silus*)



Atlantic
Argentine
(*Argentina silus*)





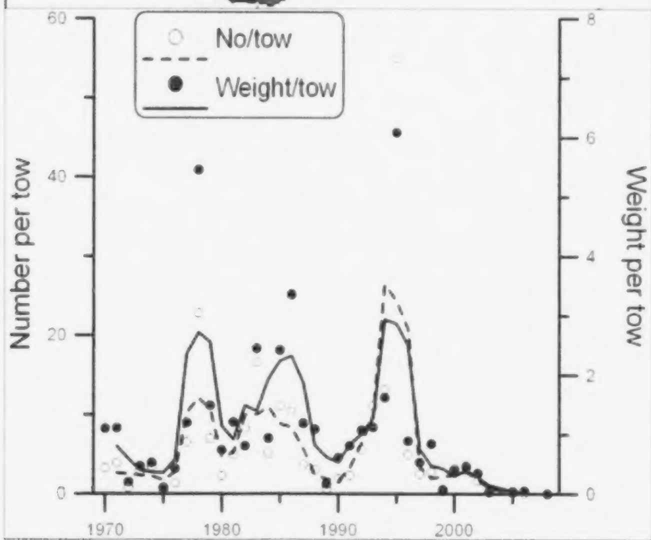
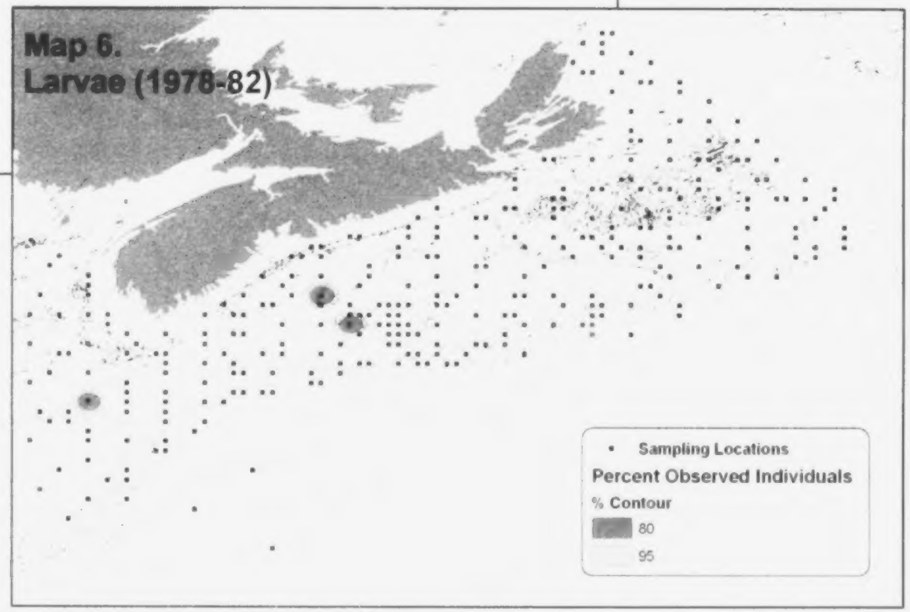


Figure 1. Population Trend



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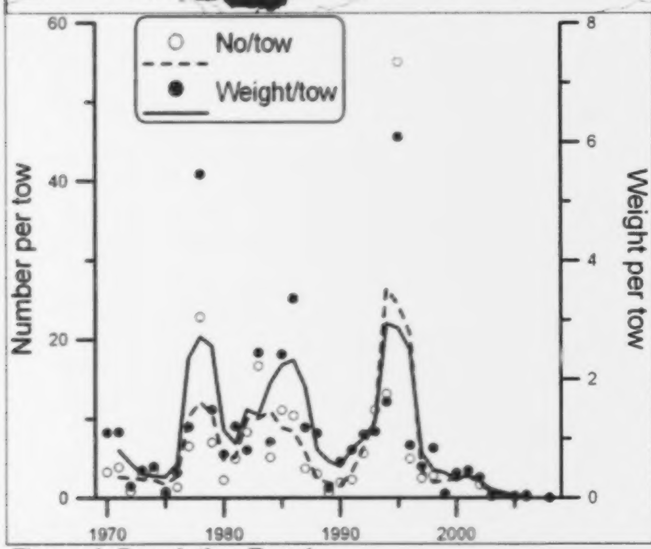

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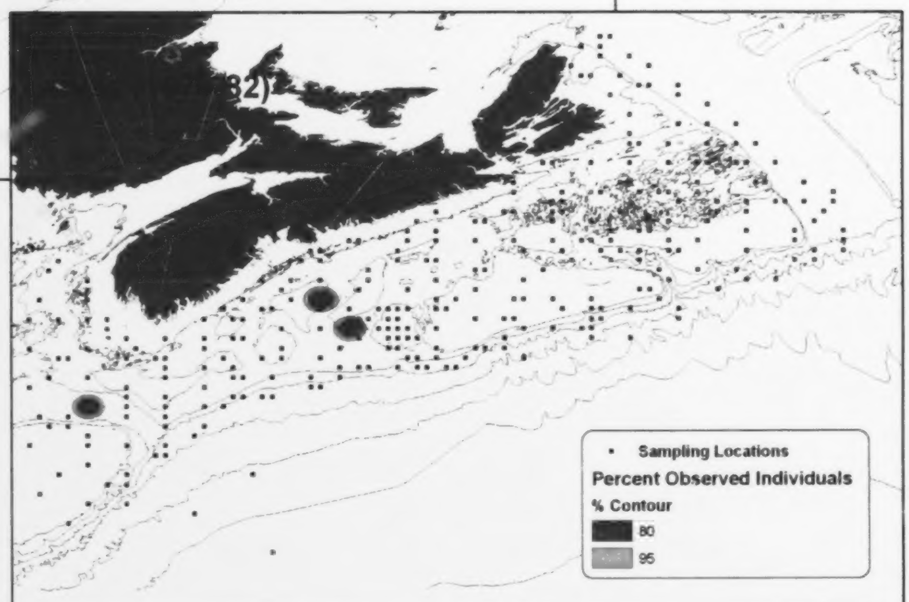
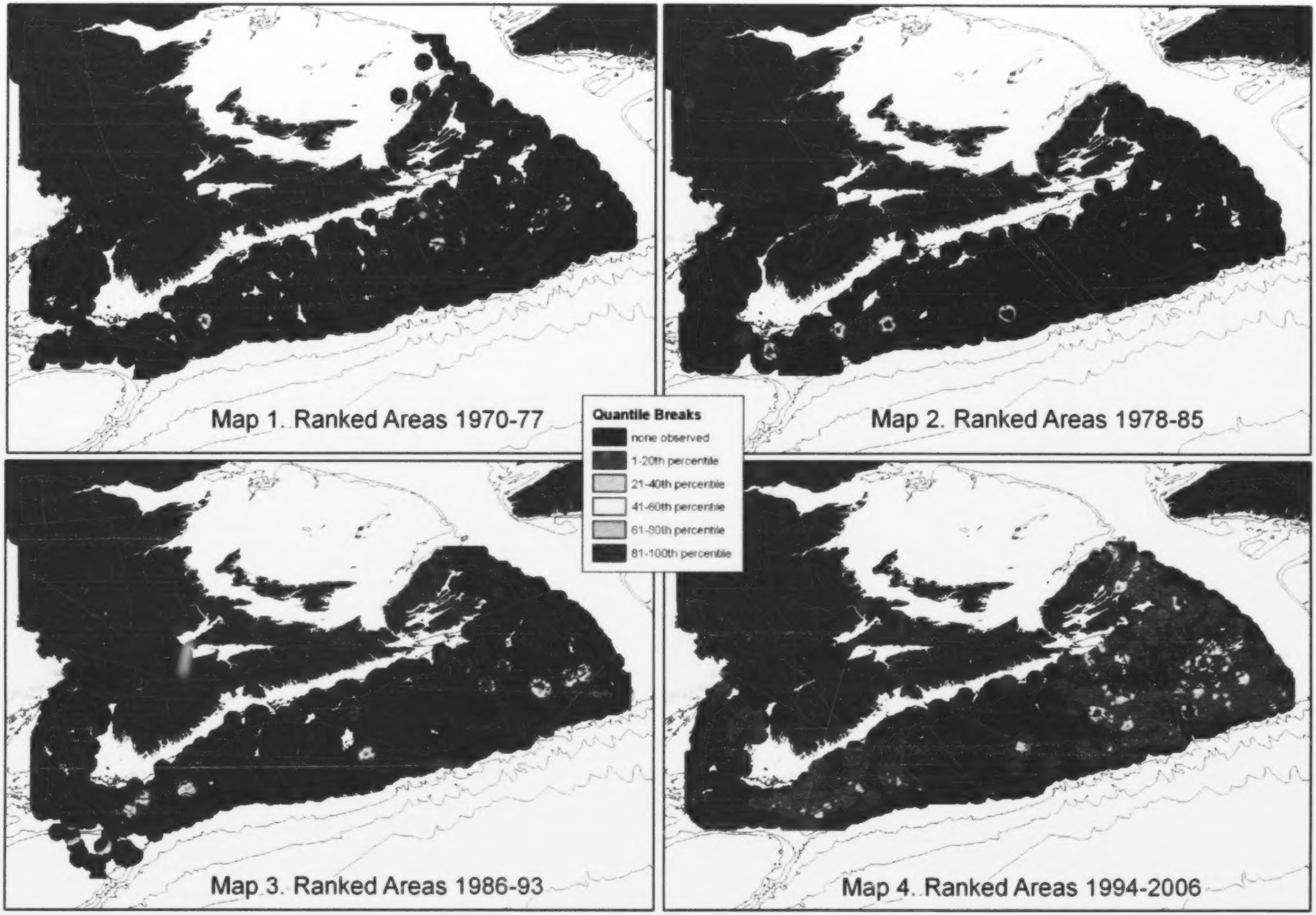


Moustache Sculpin (*Triglops murrayi*)



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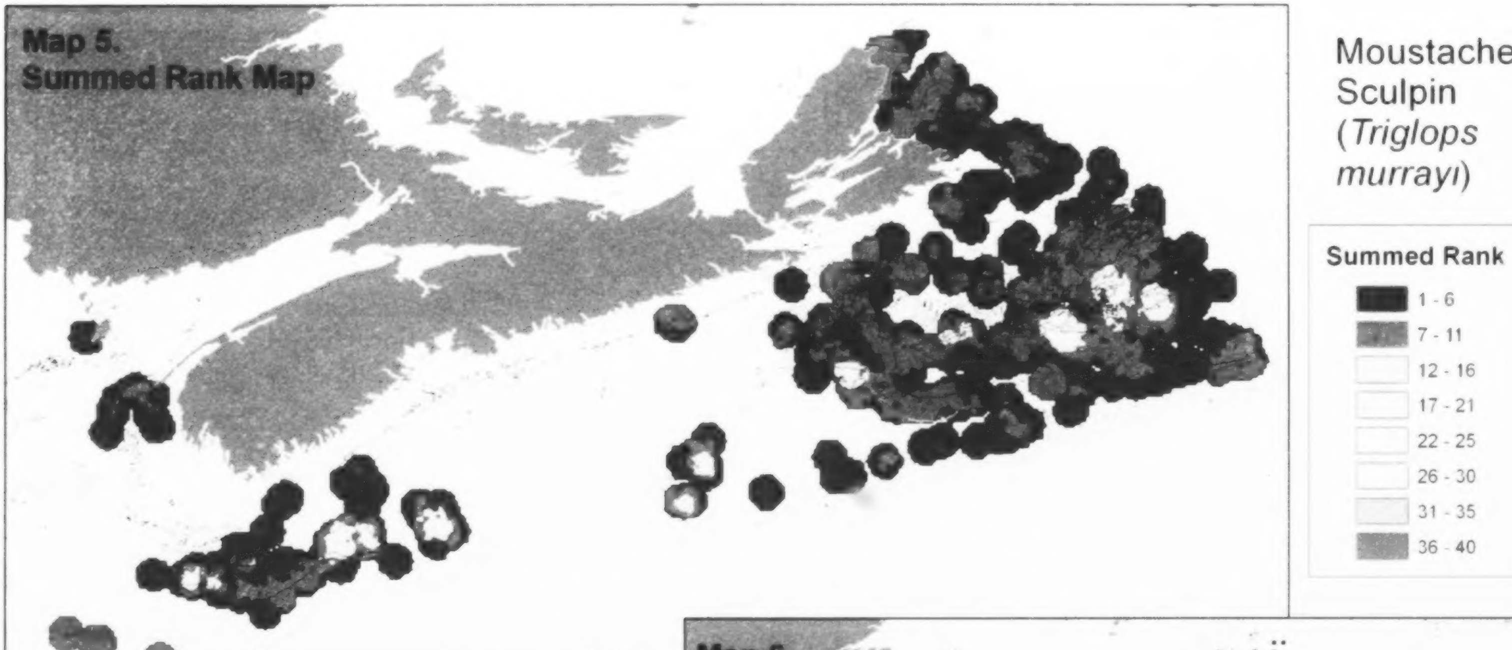


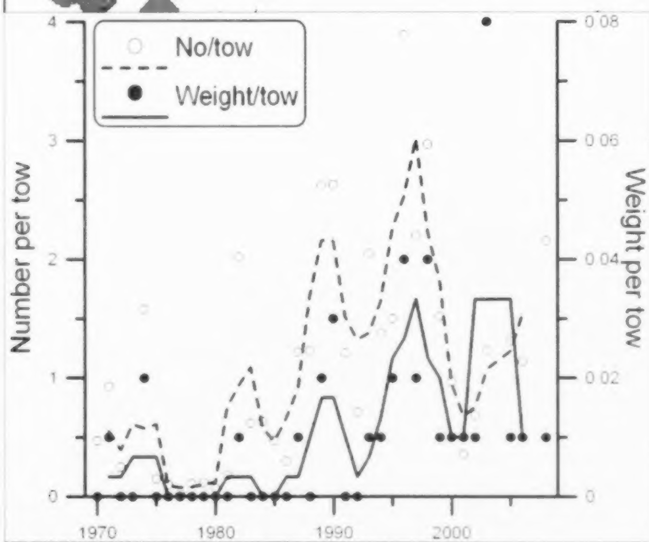
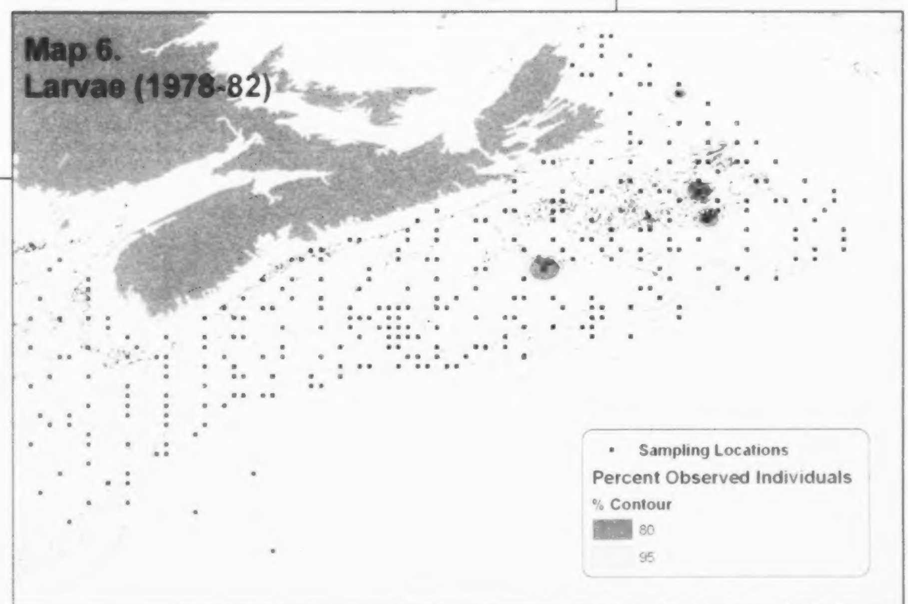
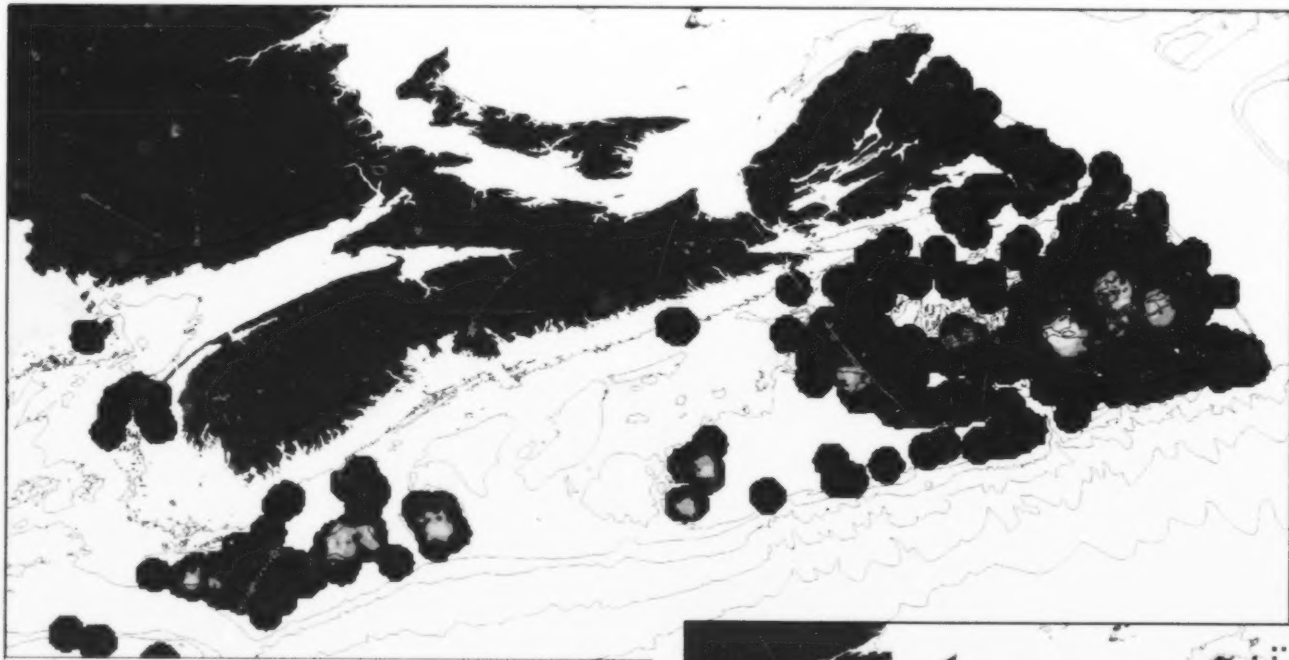


Figure 1. Population Trend



Moustache Sculpin (*Triglops murrayi*)



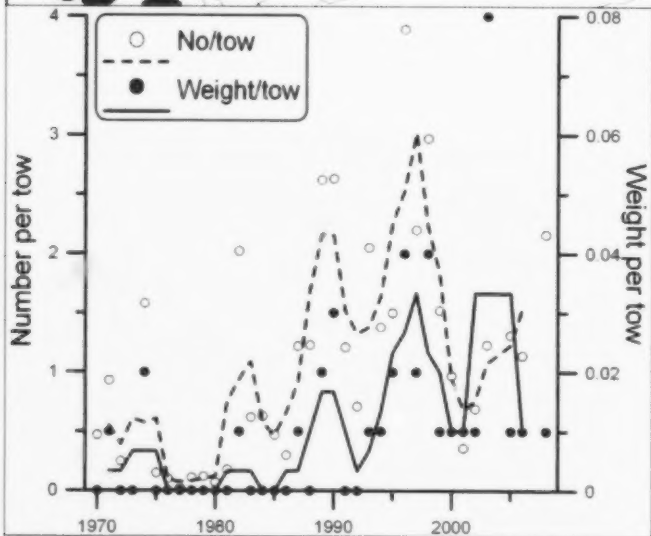
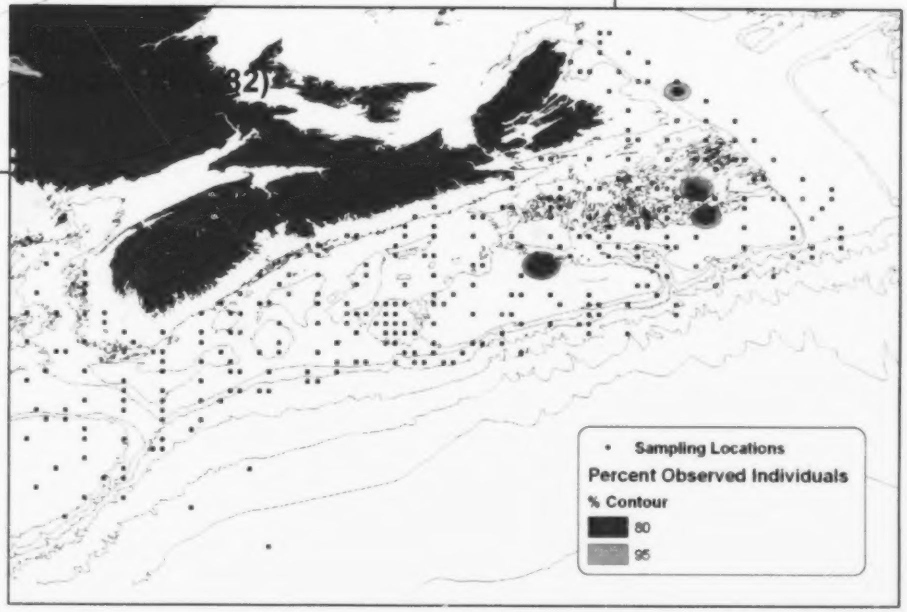
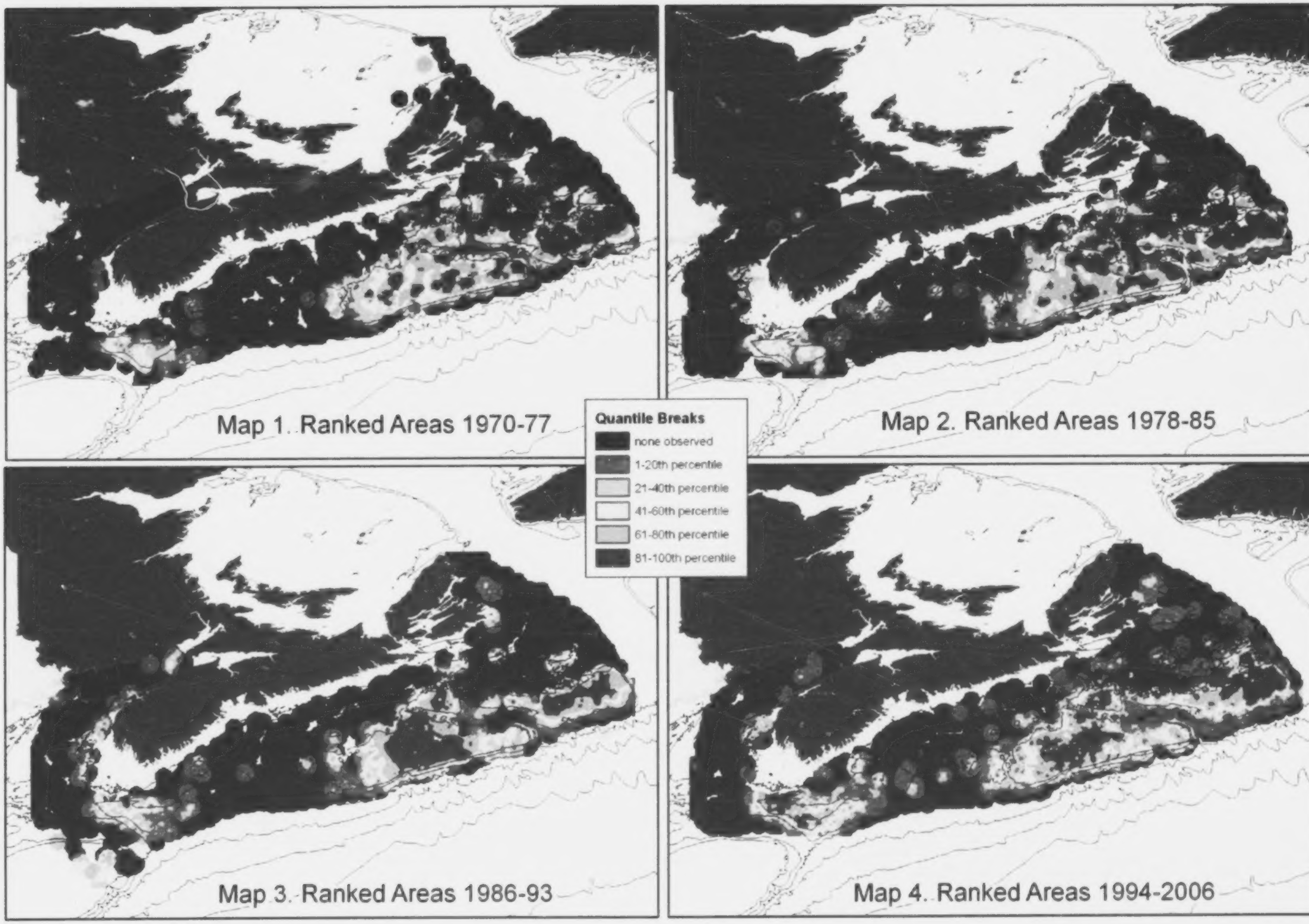


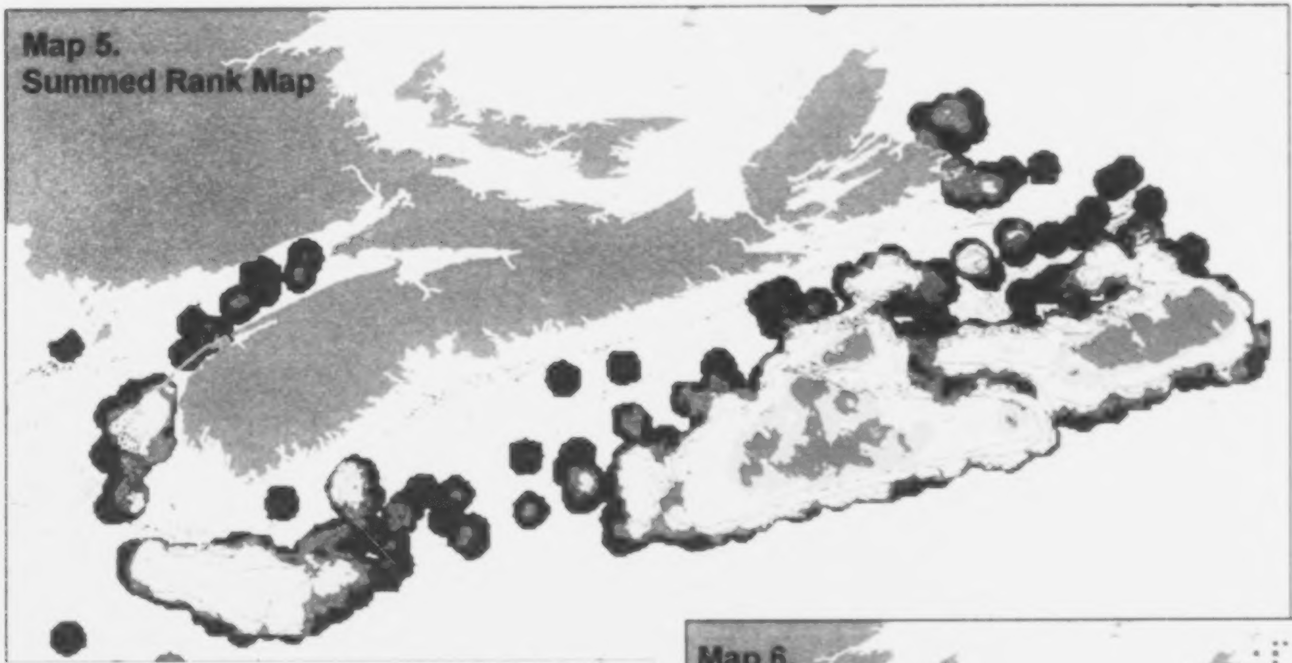
Figure 1. Population Trend





Yellowtail founder (*Limanda ferruginea*)

Yellowtail Flounder (*Limanda ferruginea*)



Summed Rank

- 1 - 6
- 7 - 11
- 12 - 16
- 17 - 21
- 22 - 25
- 26 - 30
- 31 - 35
- 36 - 40

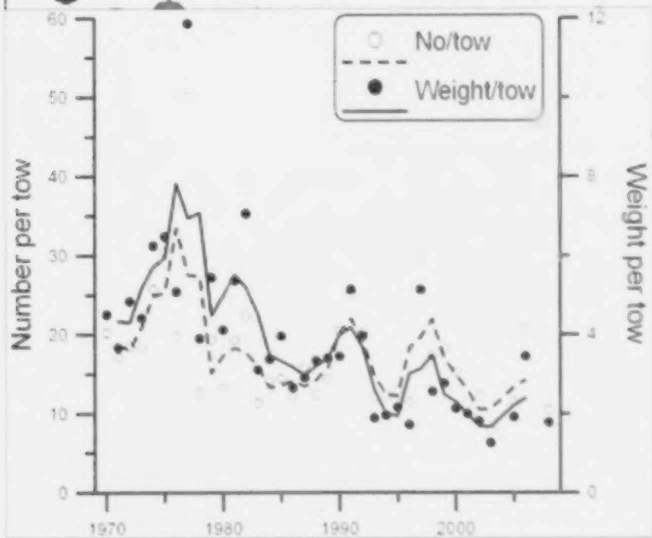
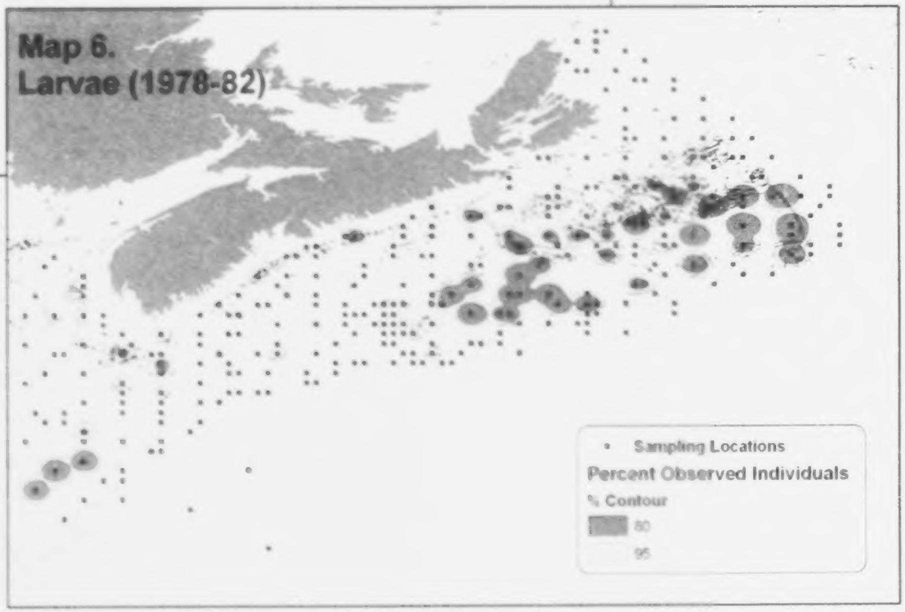
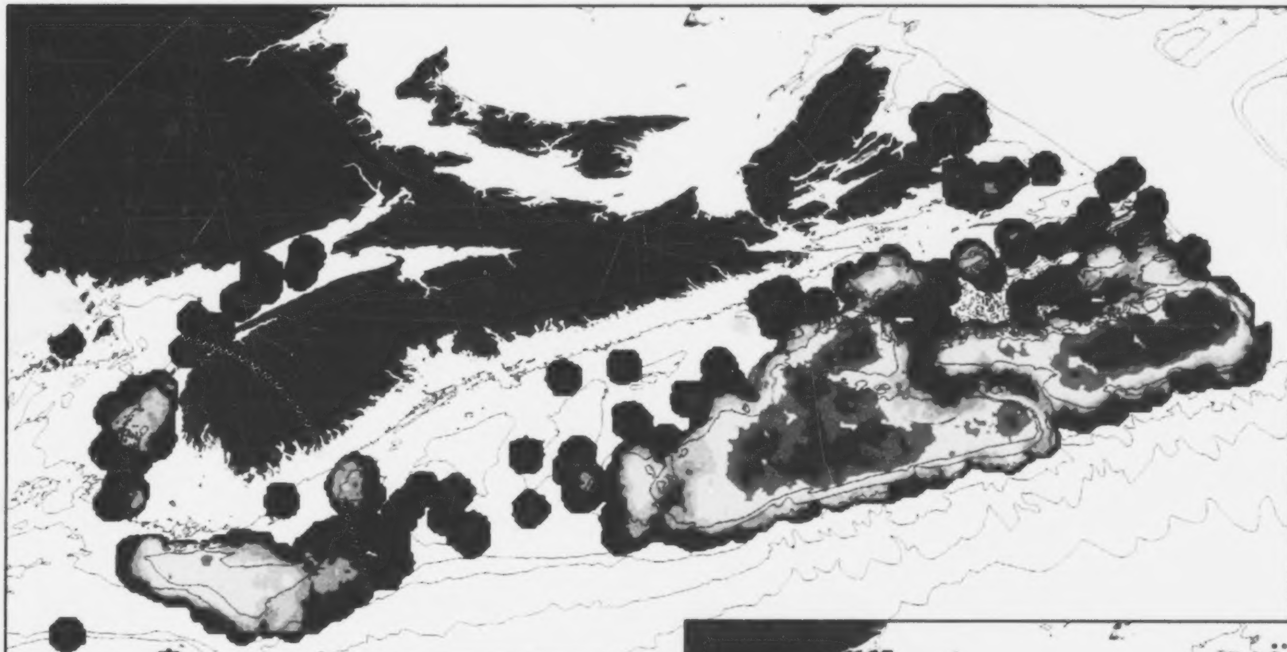


Figure 1. Population Trend



Yellowtail Flounder (*Limanda ferruginea*)



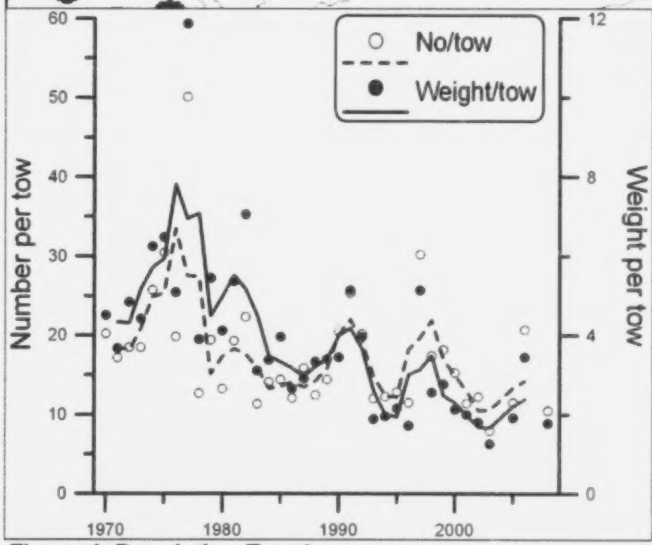
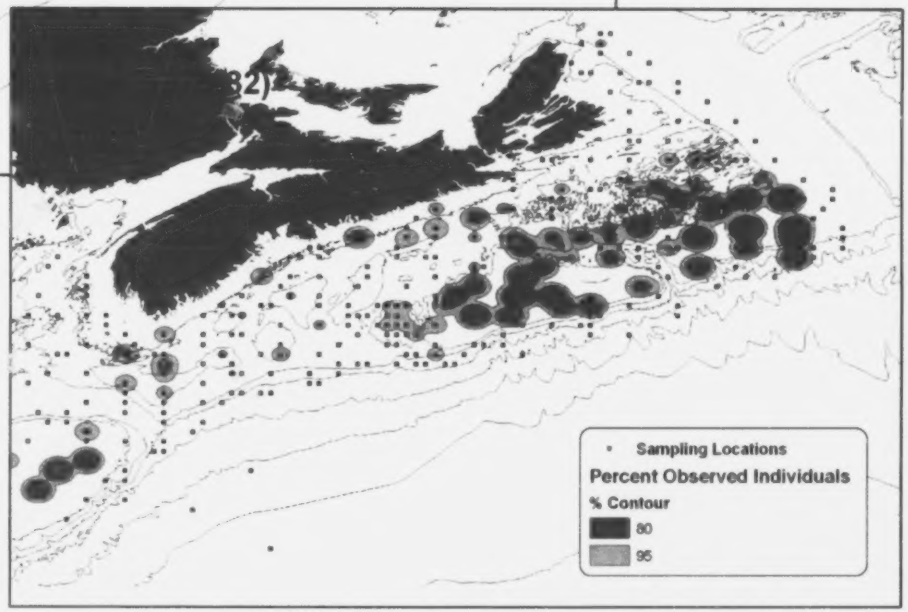
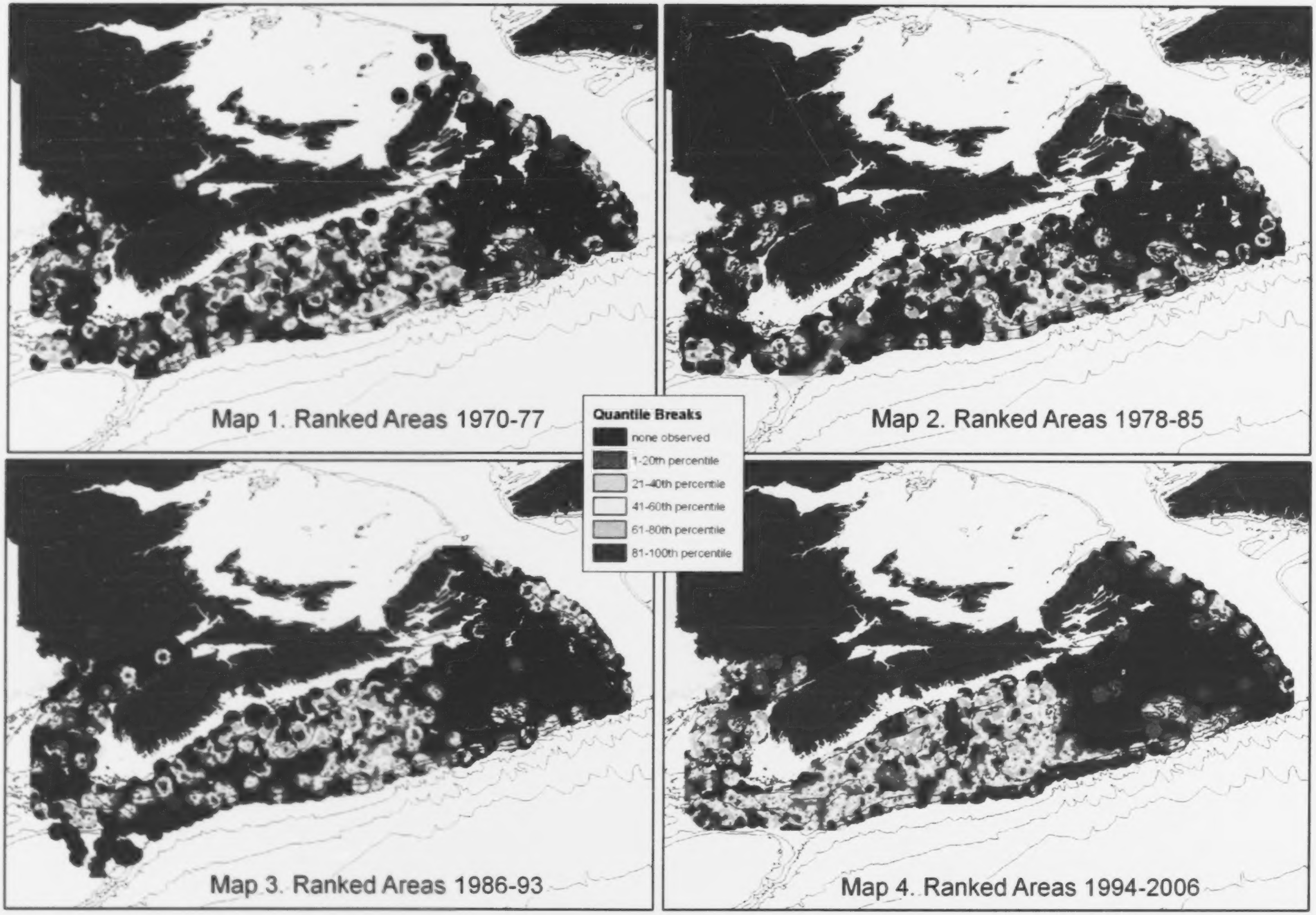


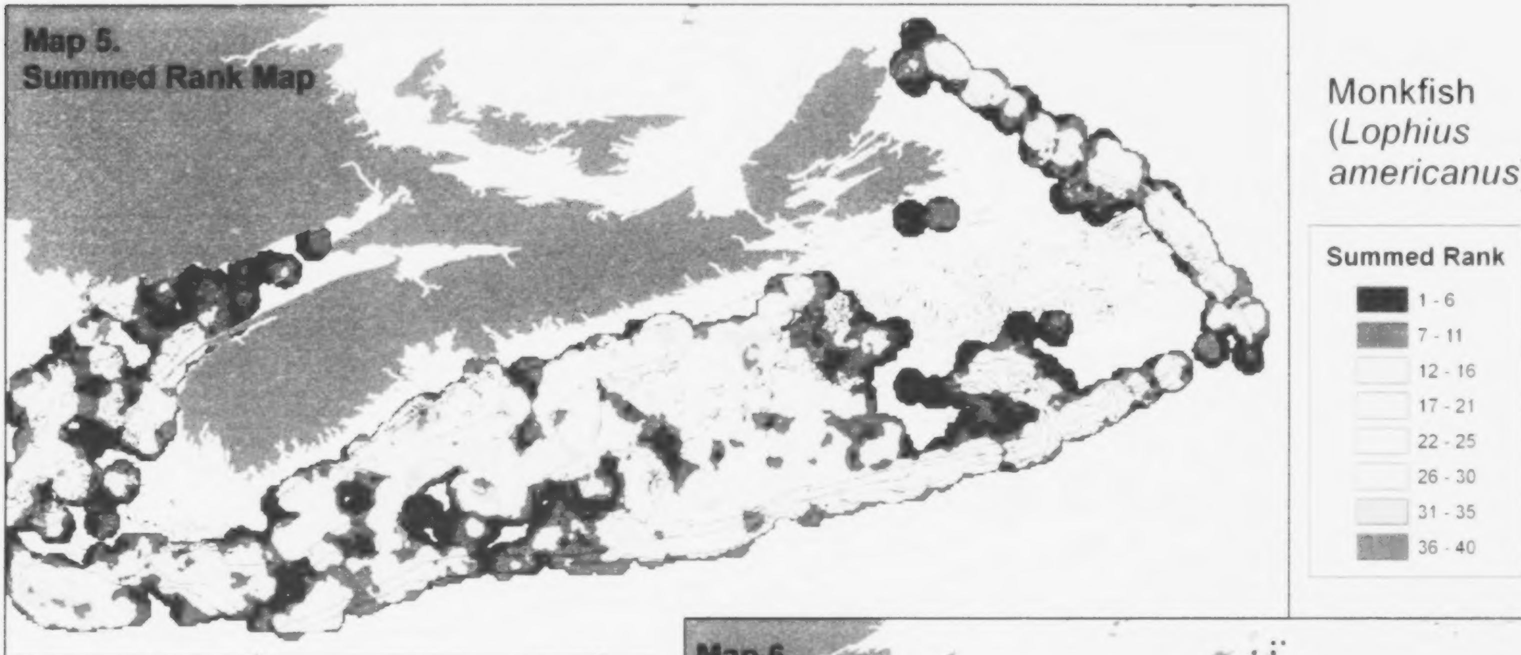
Figure 1. Population Trend





Monkfish (*Lophius americanus*)

Monkfish (*Lophius americanus*)



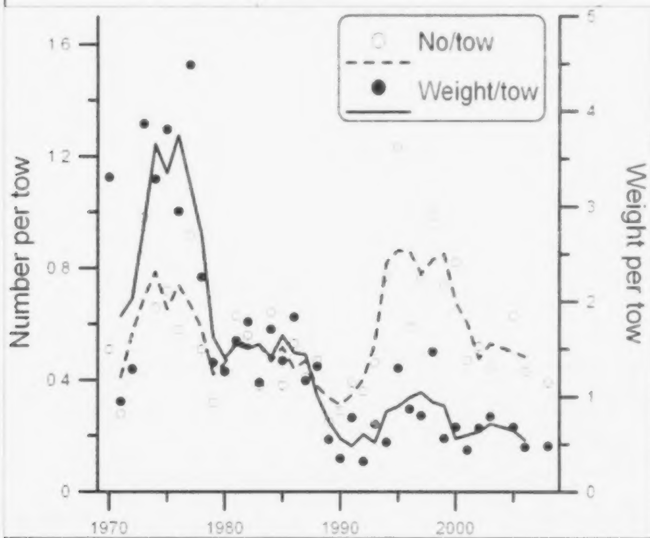
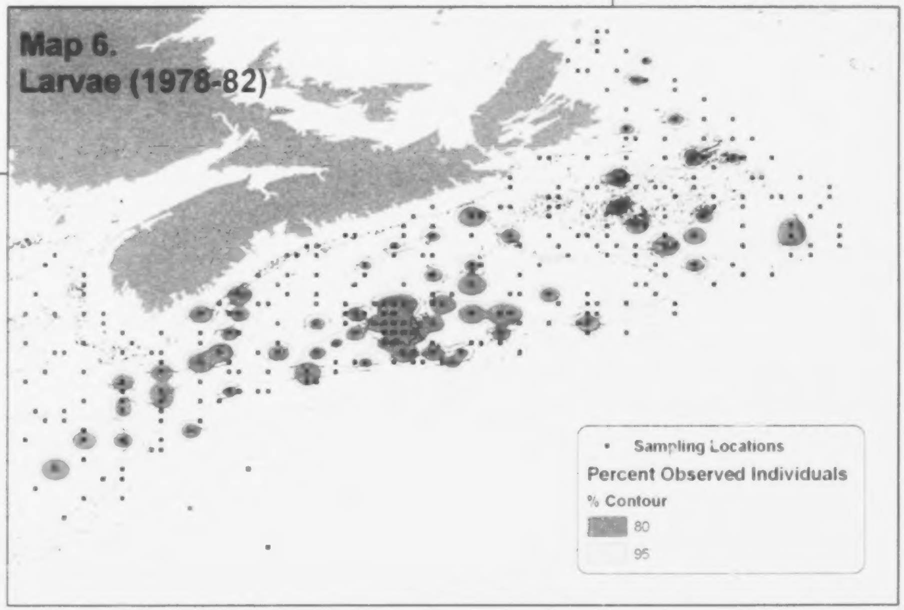
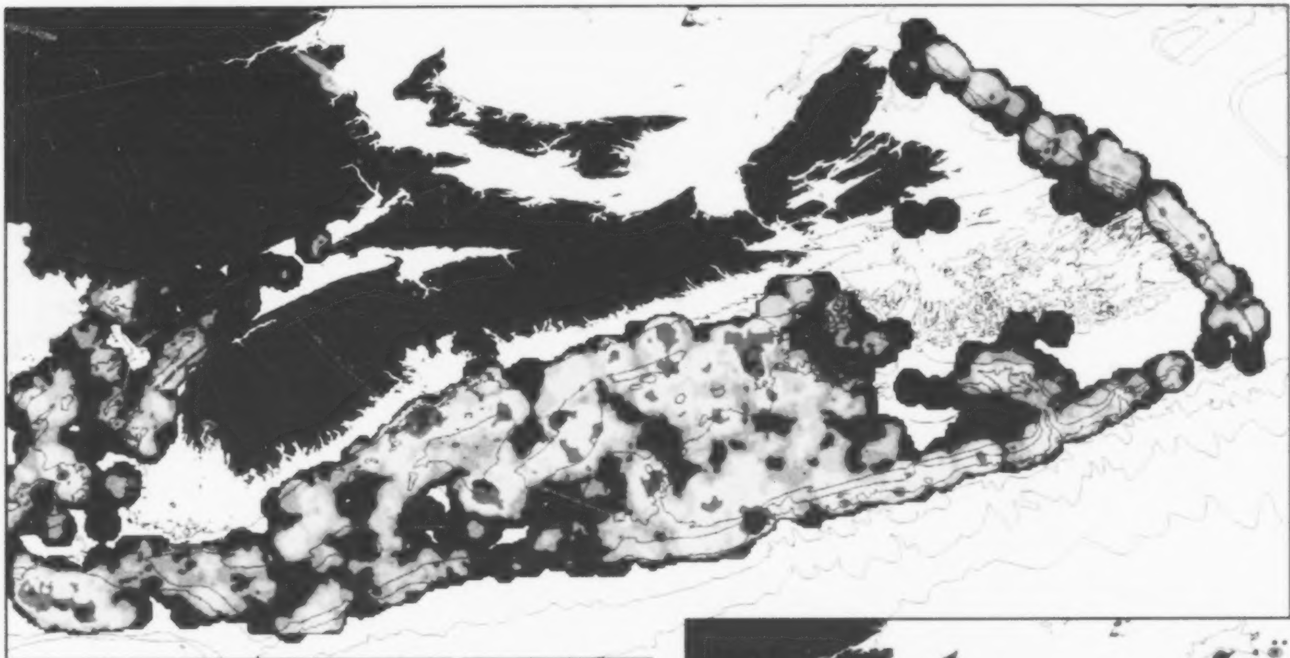
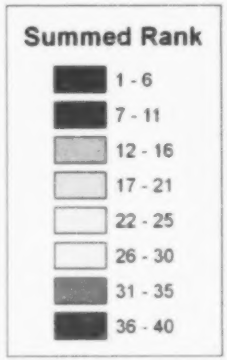


Figure 1. Population Trend



Monkfish (*Lophius americanus*)





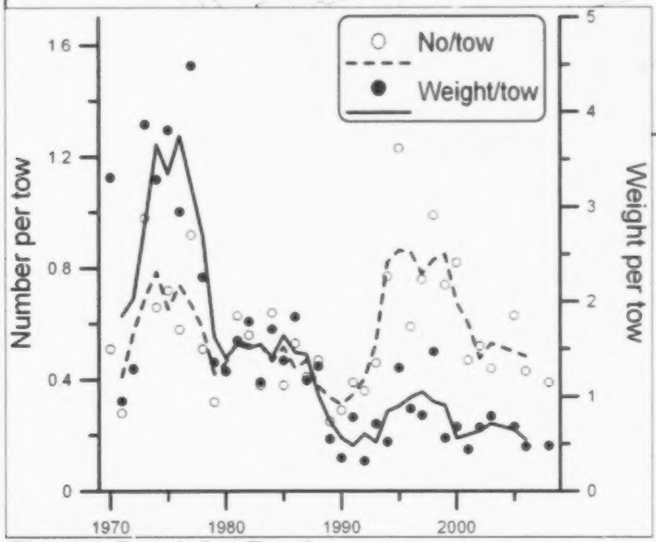
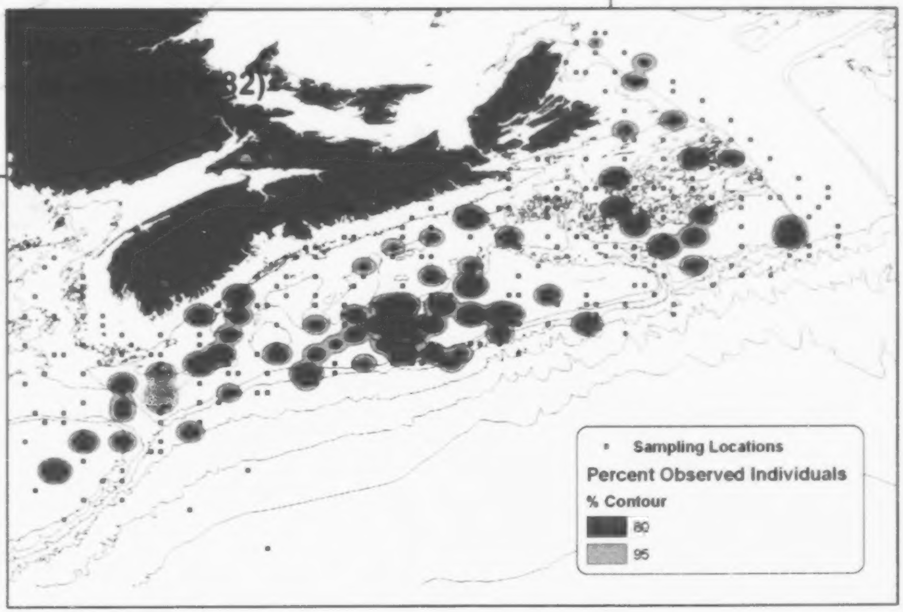
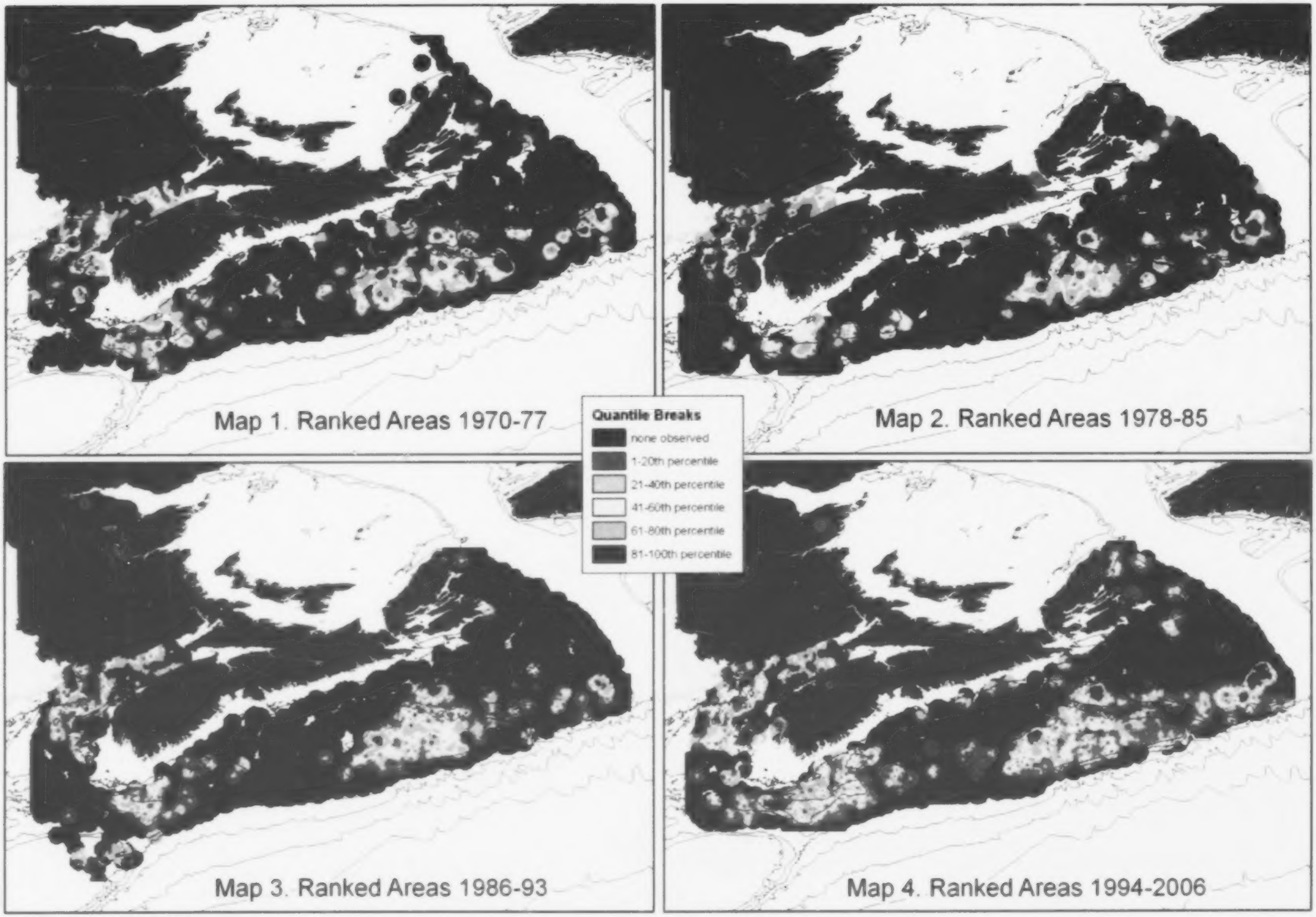
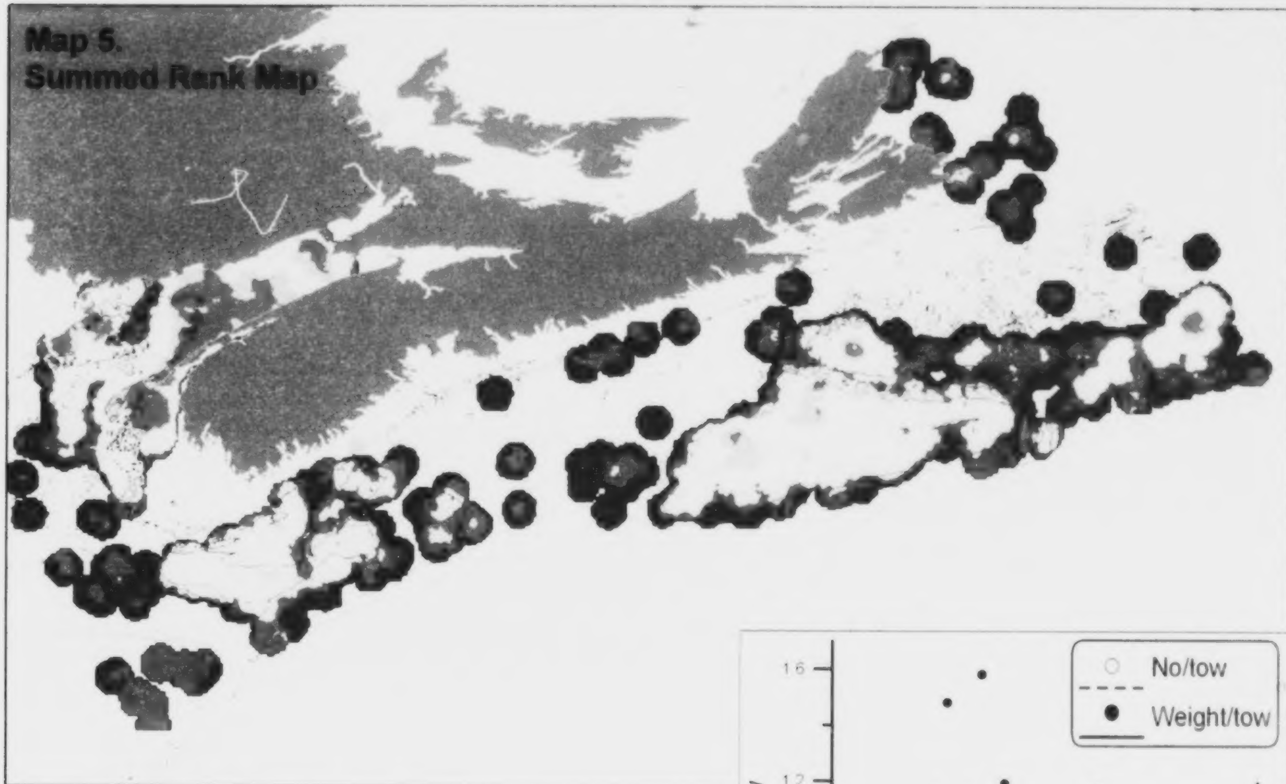


Figure 1. Population Trend

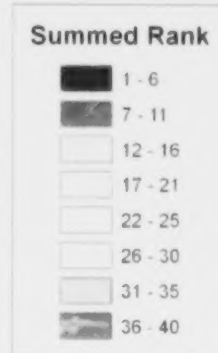


Sea Raven / Sea Sculpin (*Hemitripterus americanus*)





Sea Raven/
Sea Sculpin
(*Hemitripterus americanus*)



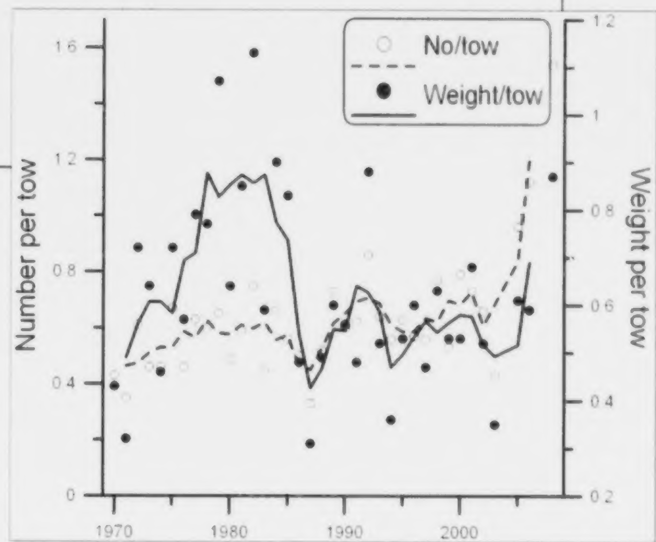
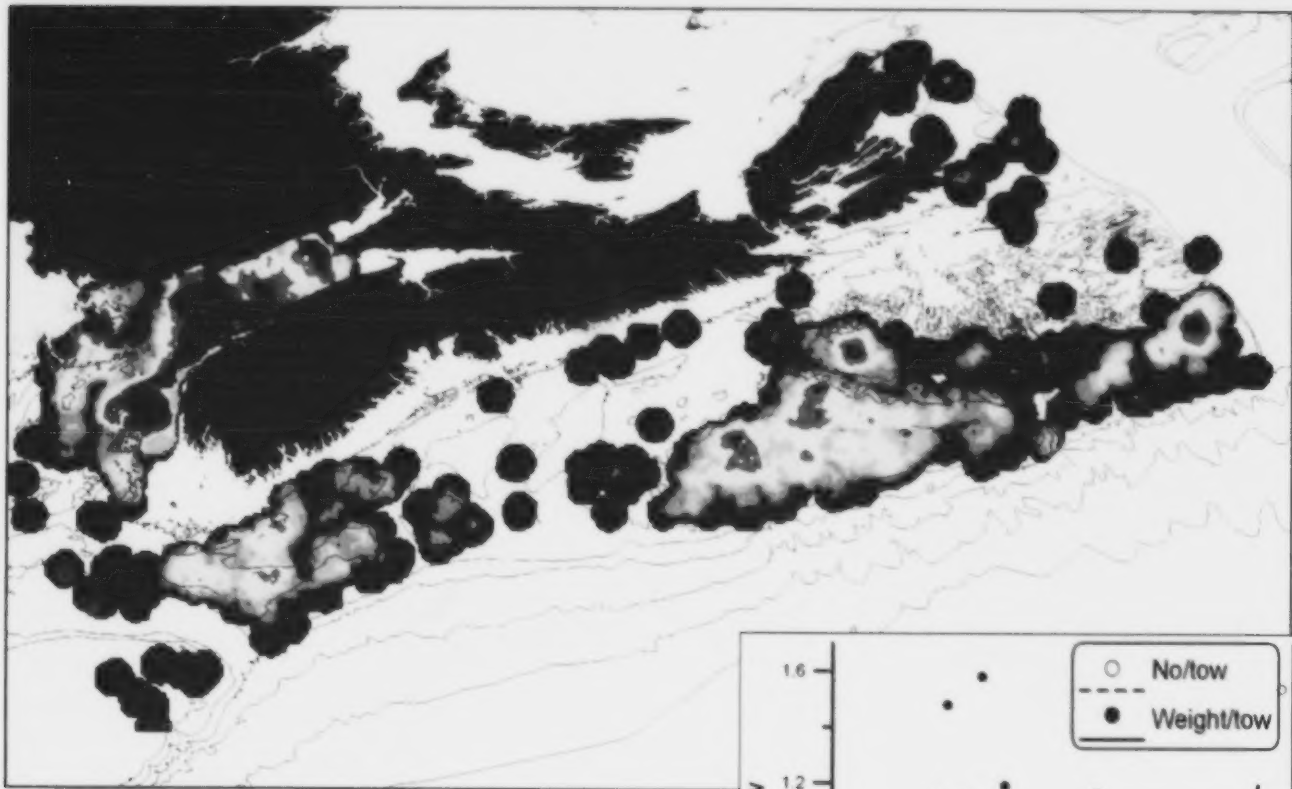


Figure 1. Population Trend

Sea Raven/ Sea Sculpin (*Hemitripterus americanus*)



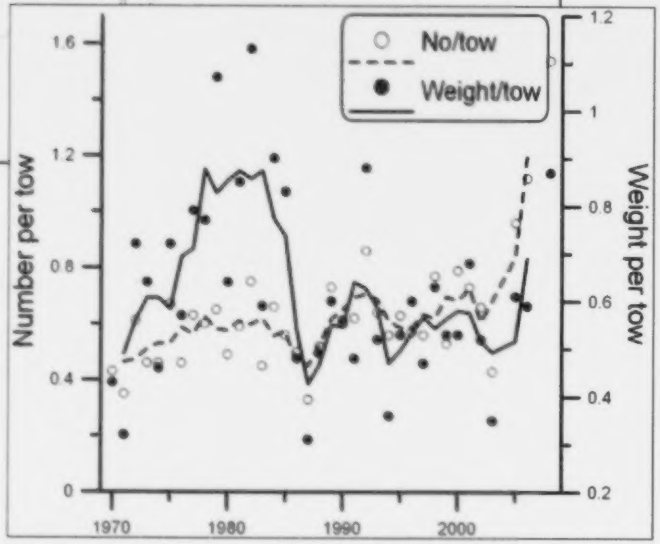
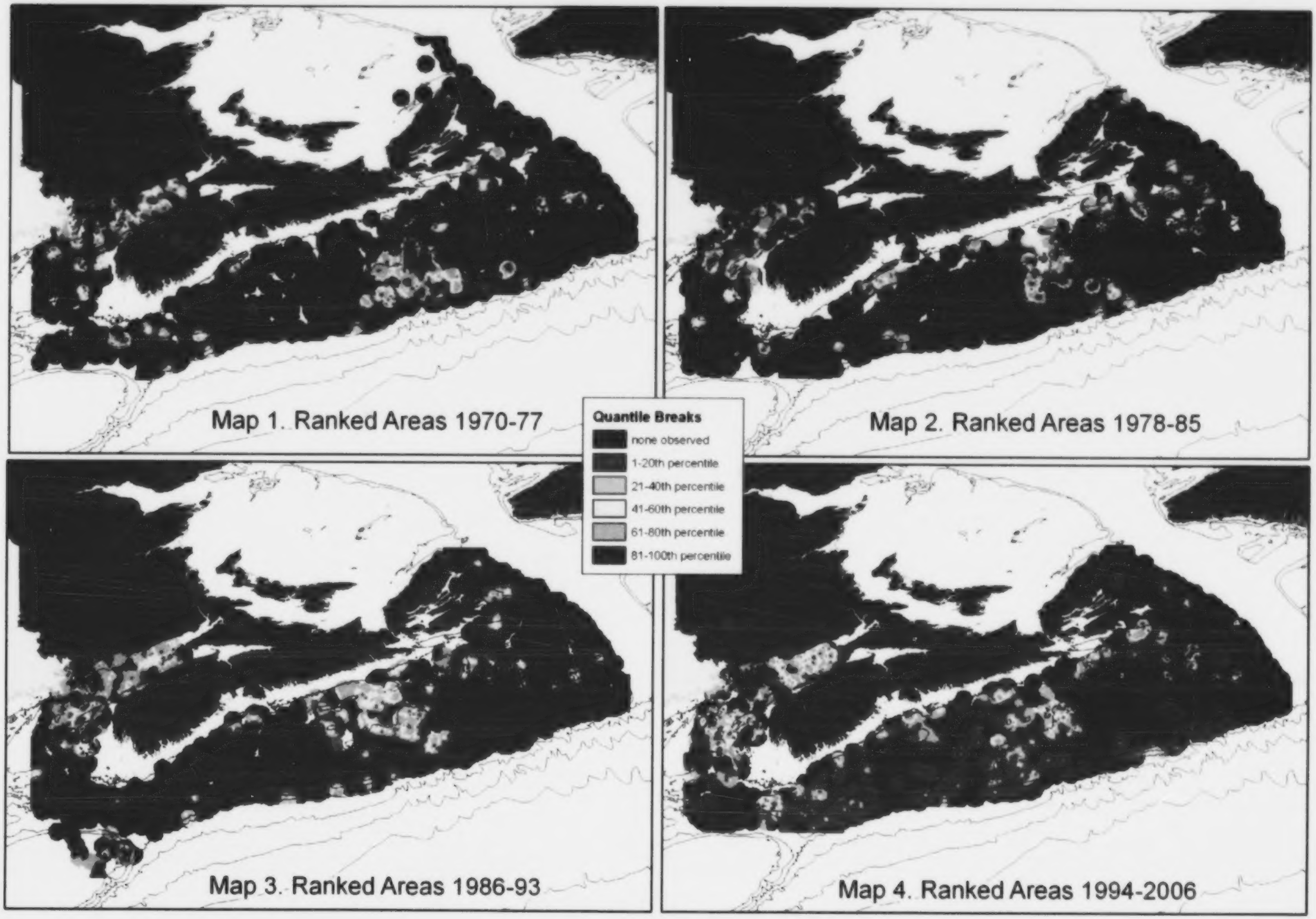
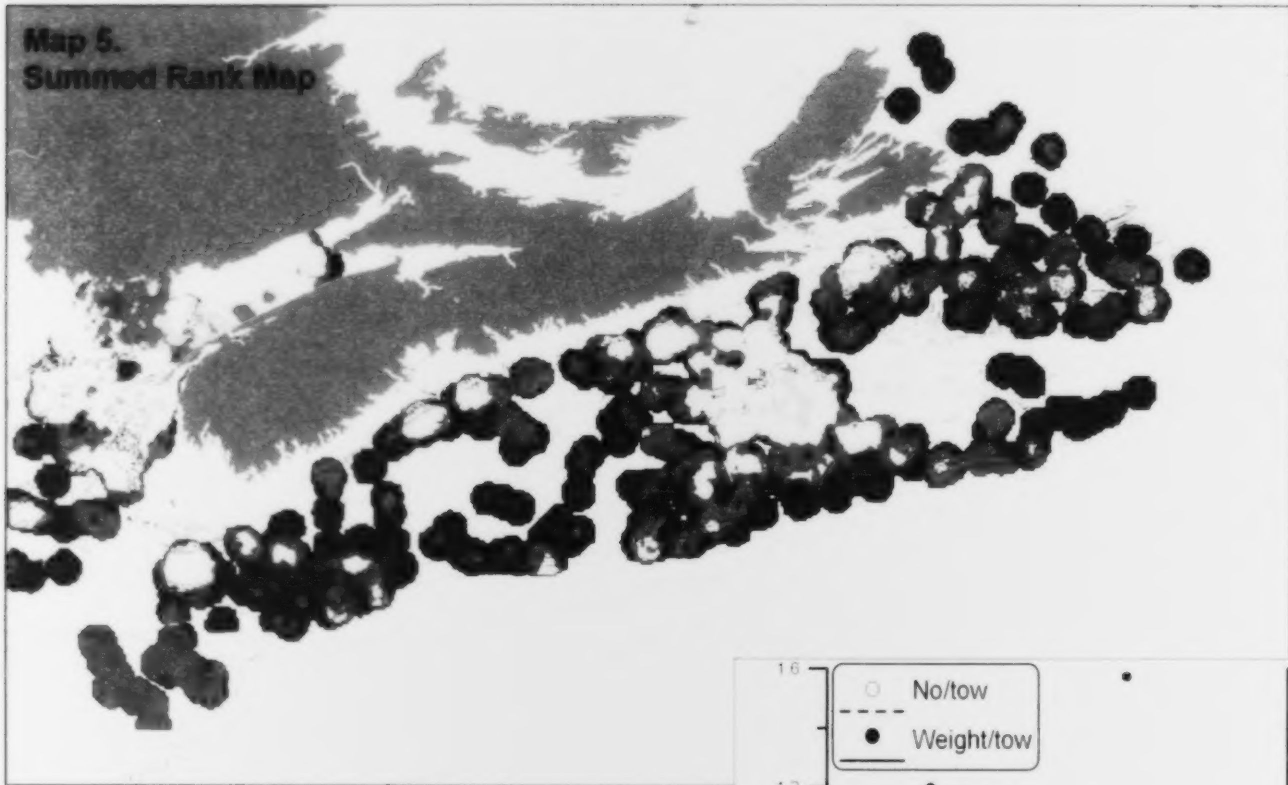


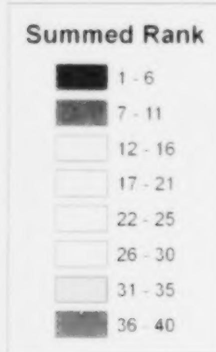
Figure 1. Population Trend

Ocean Pout (Zoarces americanus)





Ocean Pout
(*Zoarces americanus*)



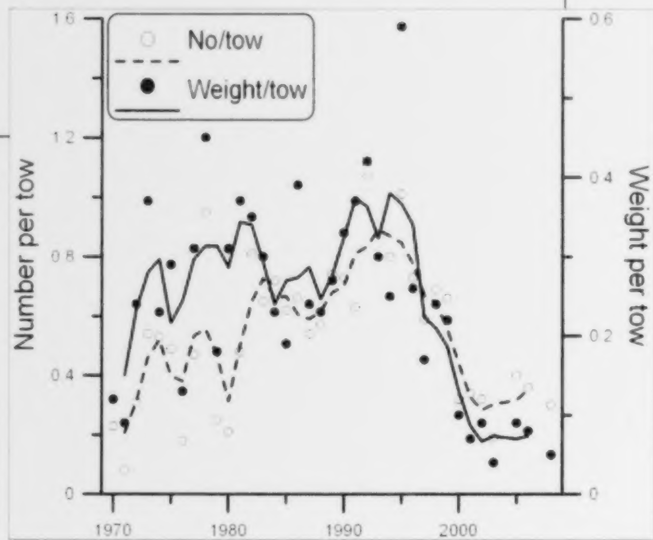
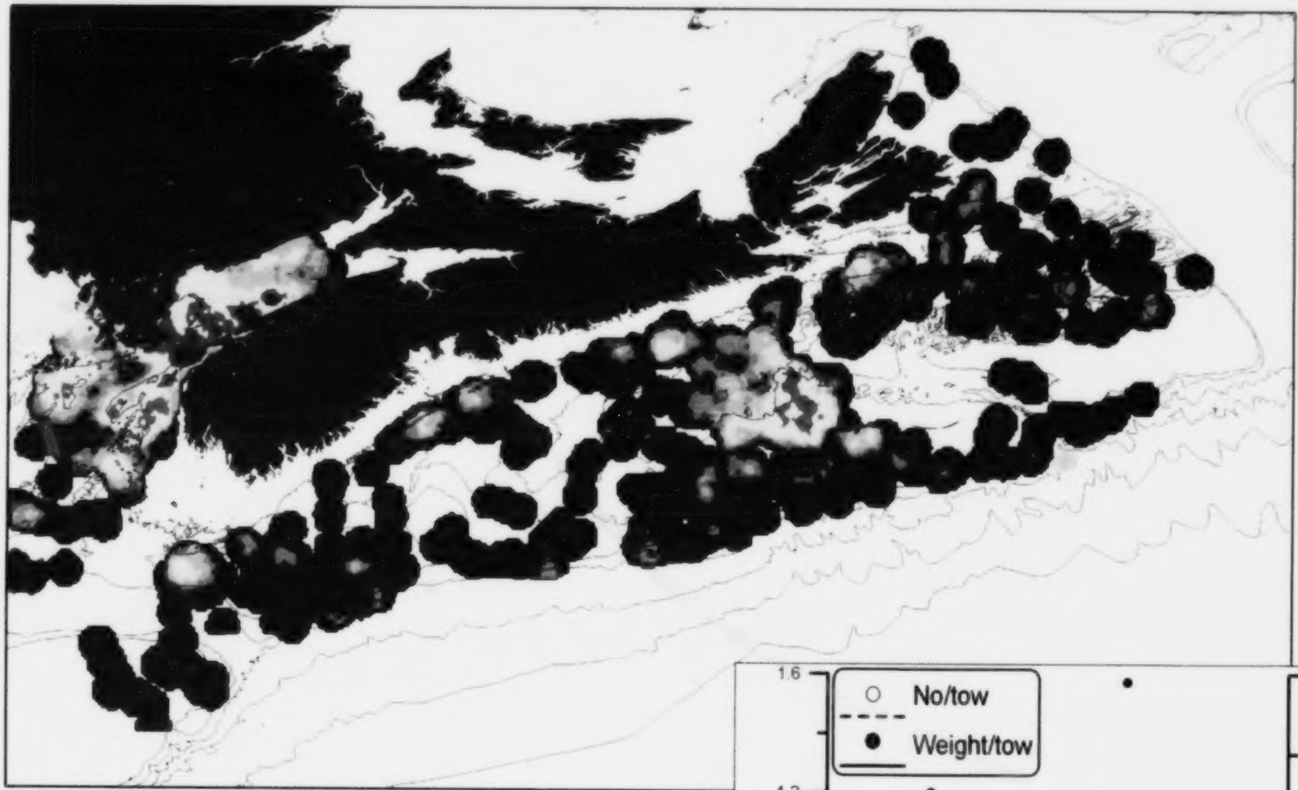
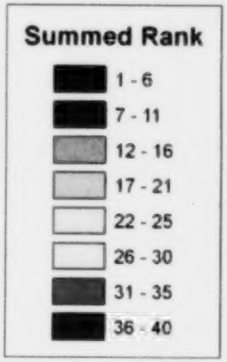


Figure 1. Population Trend

Ocean Pout
(*Zoarces americanus*)





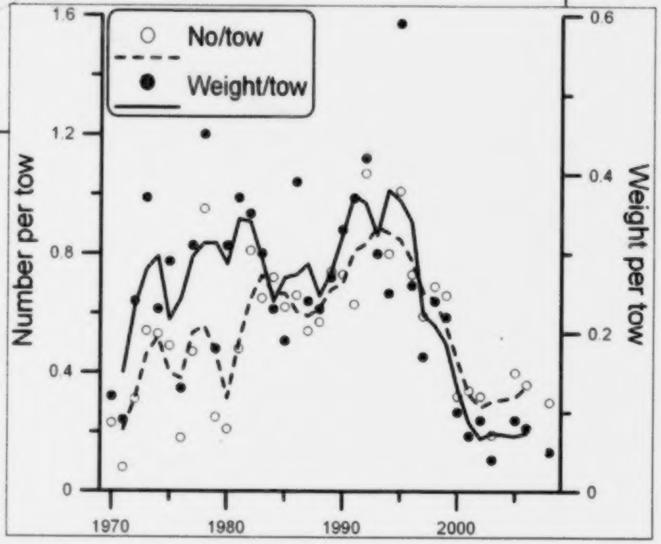
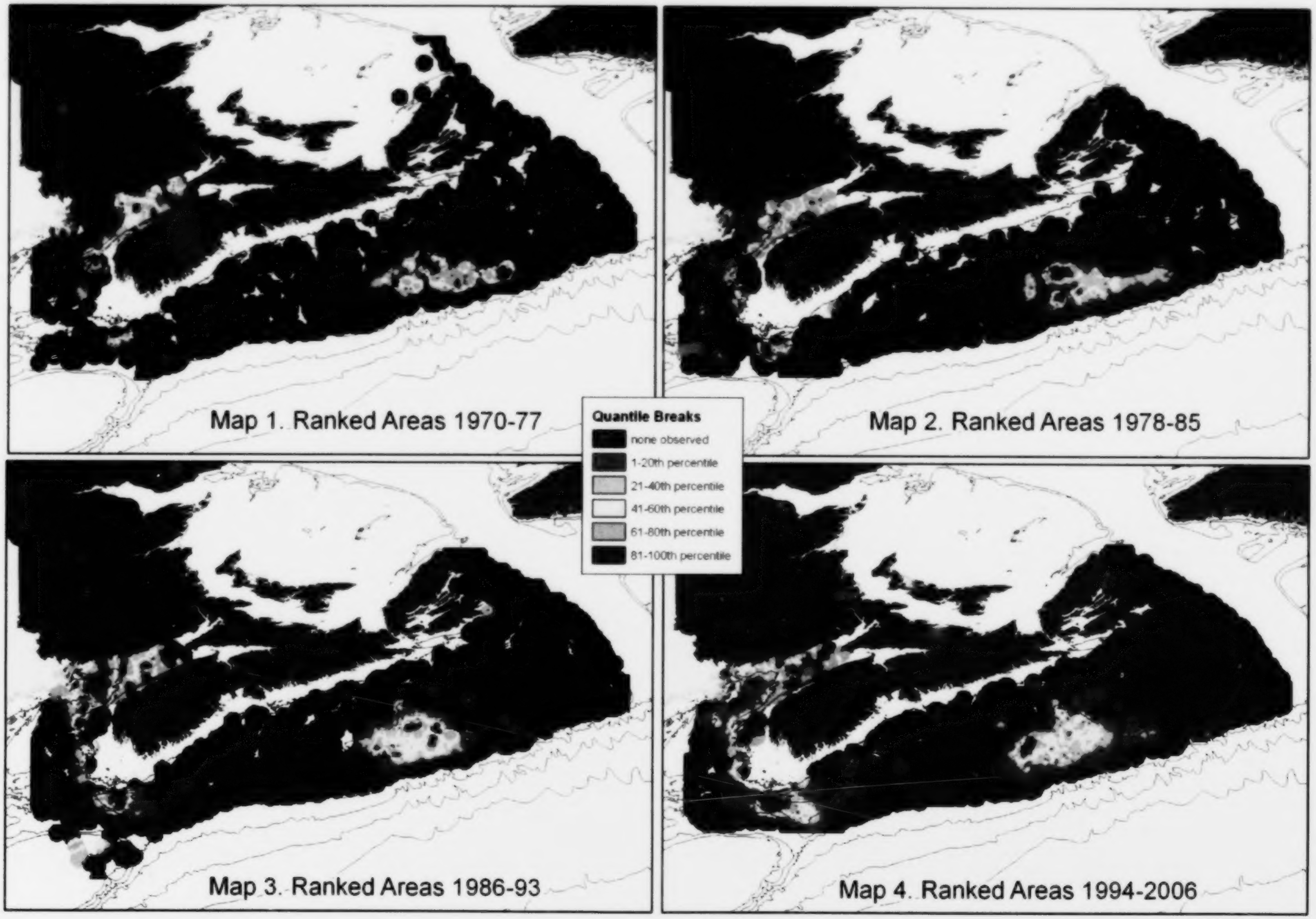
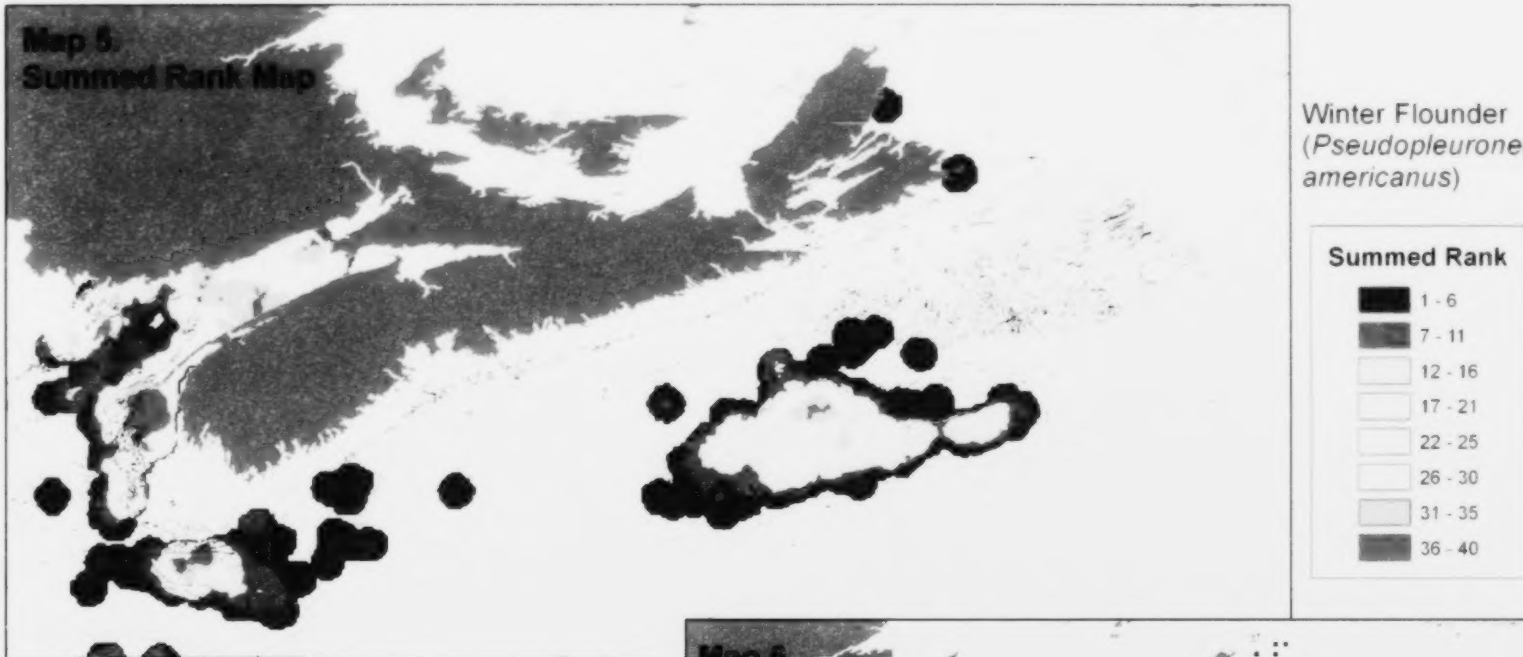


Figure 1. Population Trend

Winter Flounder (*Pseudopleuronectes americanus*)



Winter Flounder
(*Pseudopleuronectes americanus*)



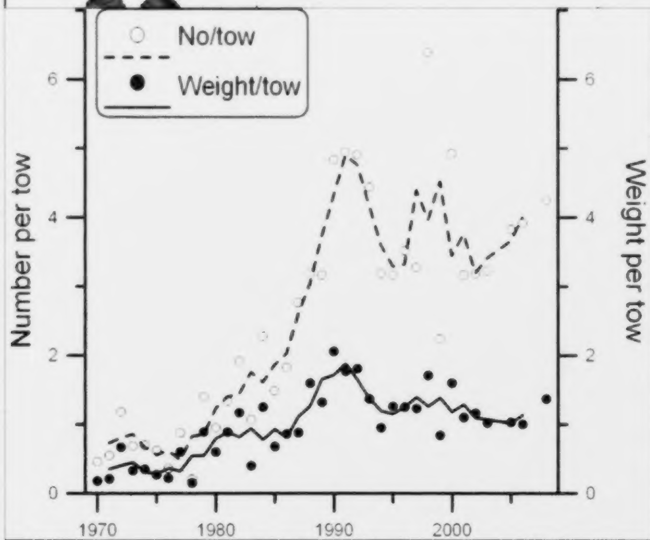
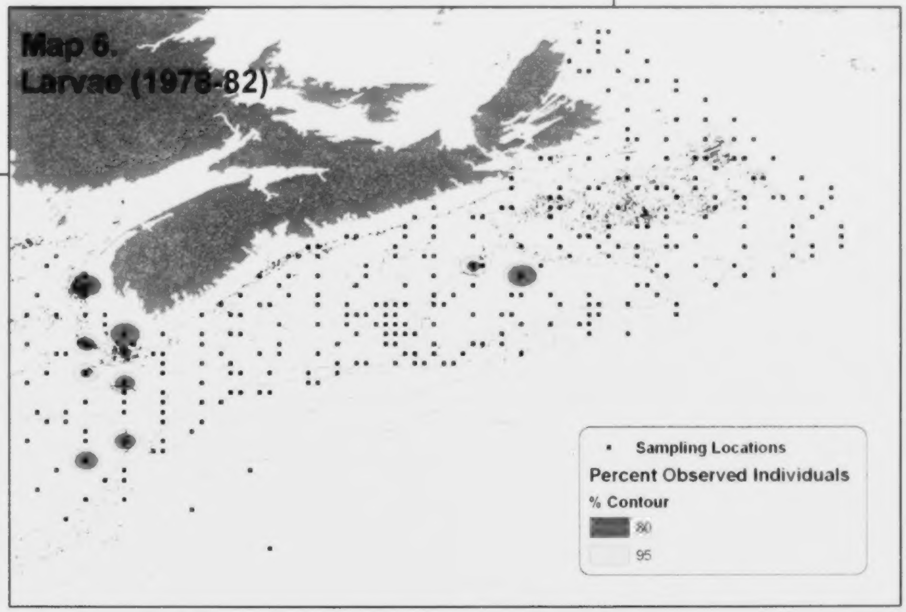
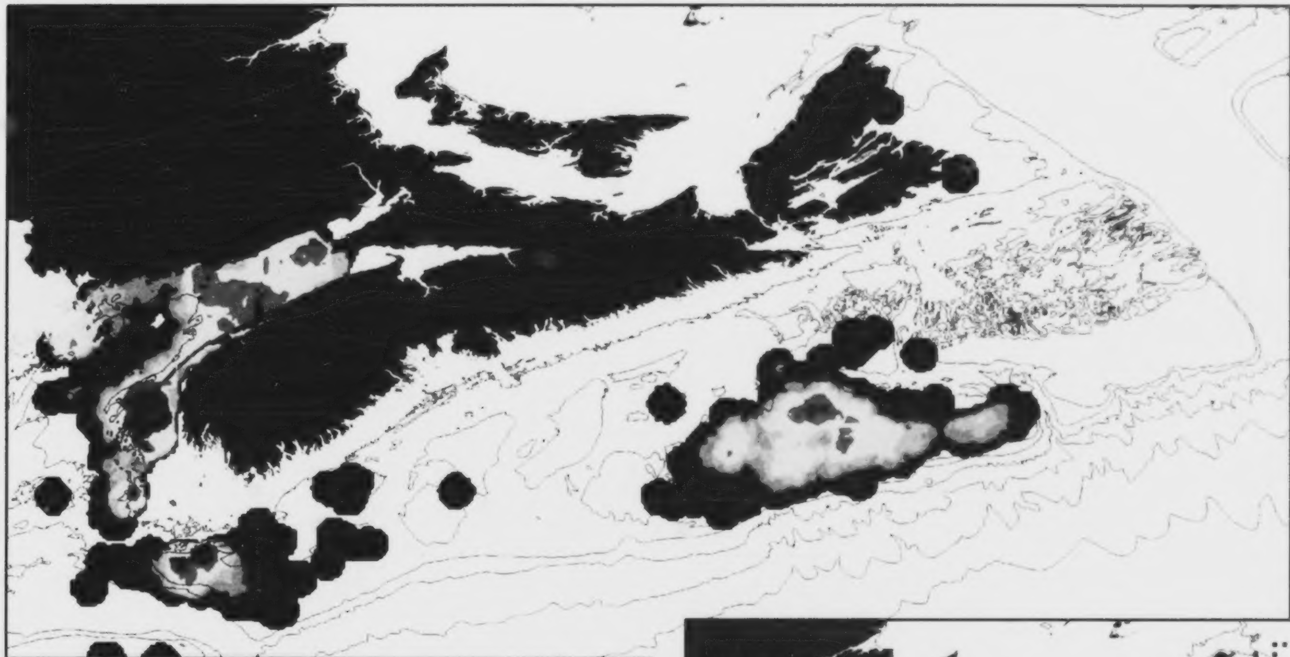


Figure 1. Population Trend



Winter Flounder (*Pseudopleuronectes americanus*)



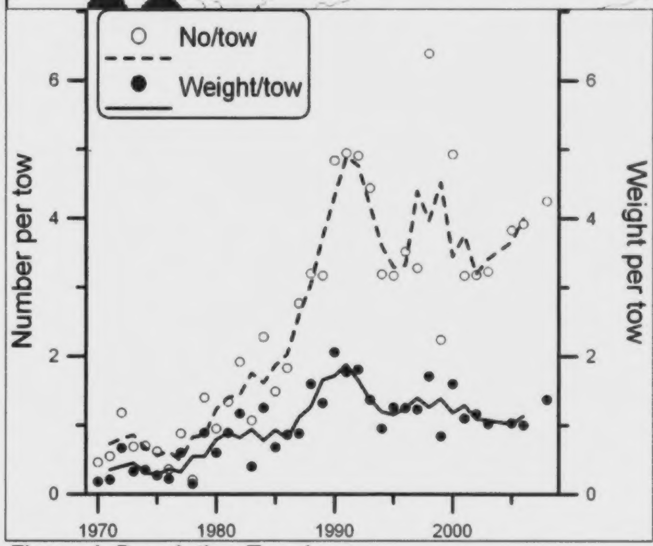
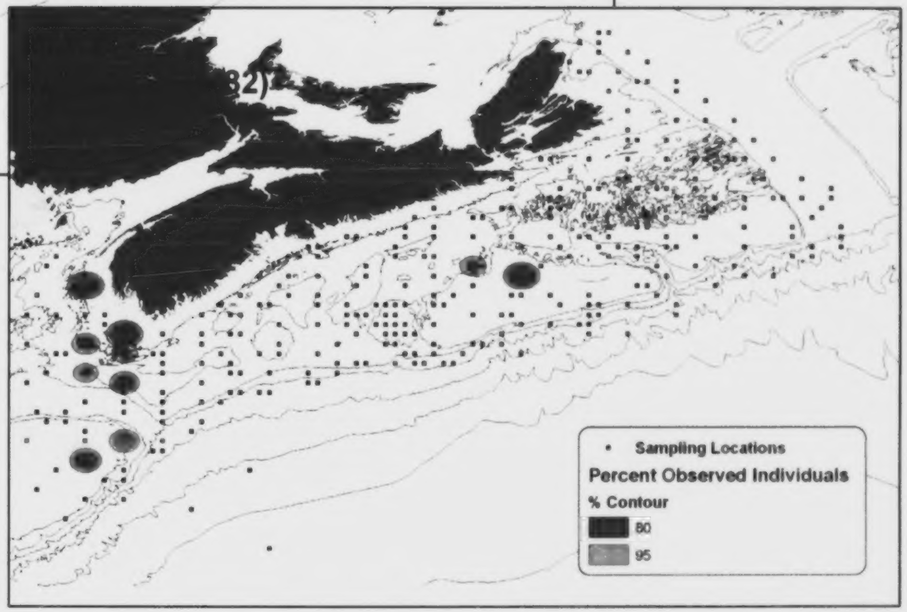
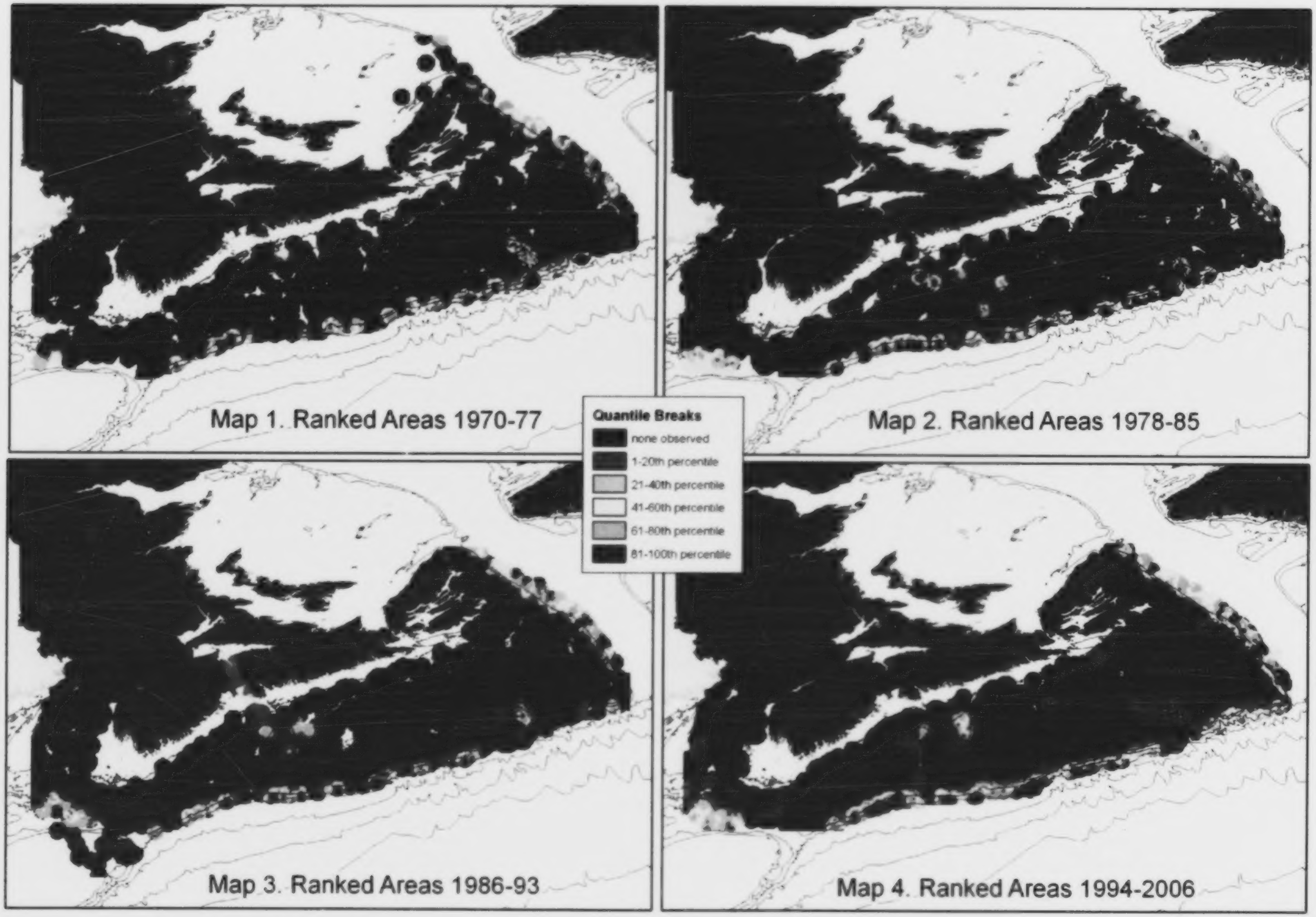


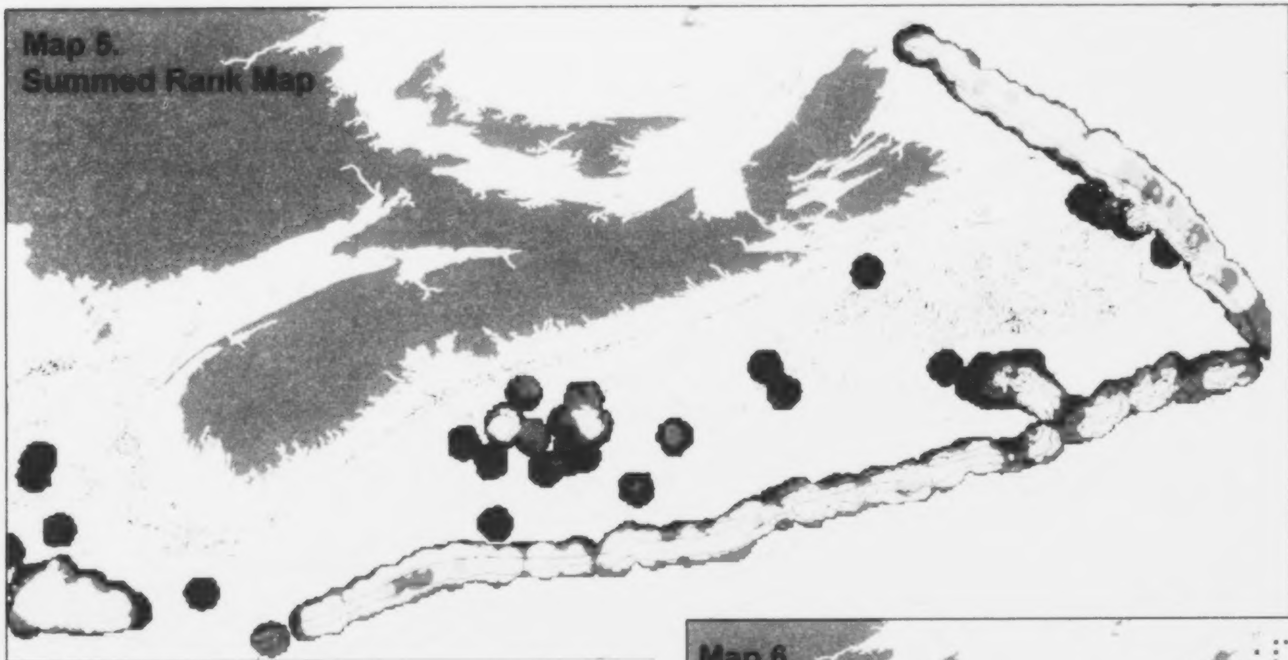
Figure 1. Population Trend

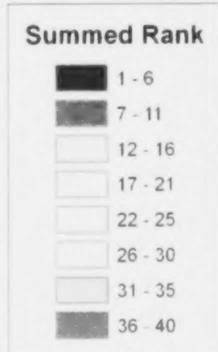




Longfin Hake (*Phycis chesteri*)

Longfin Hake
(*Phycis chesteri*)





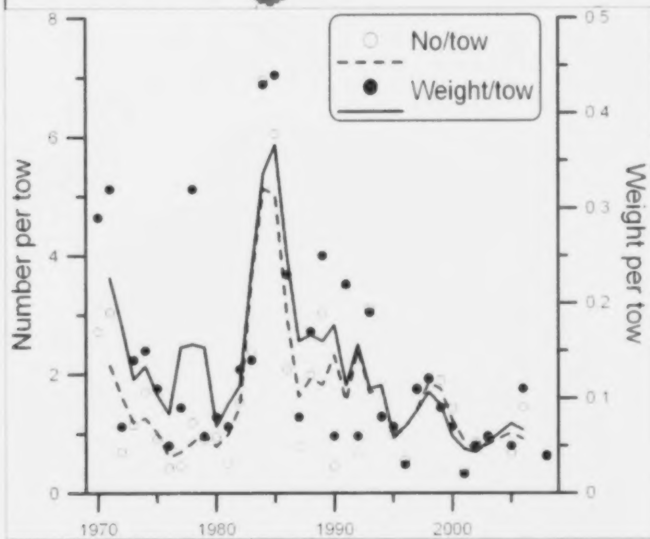
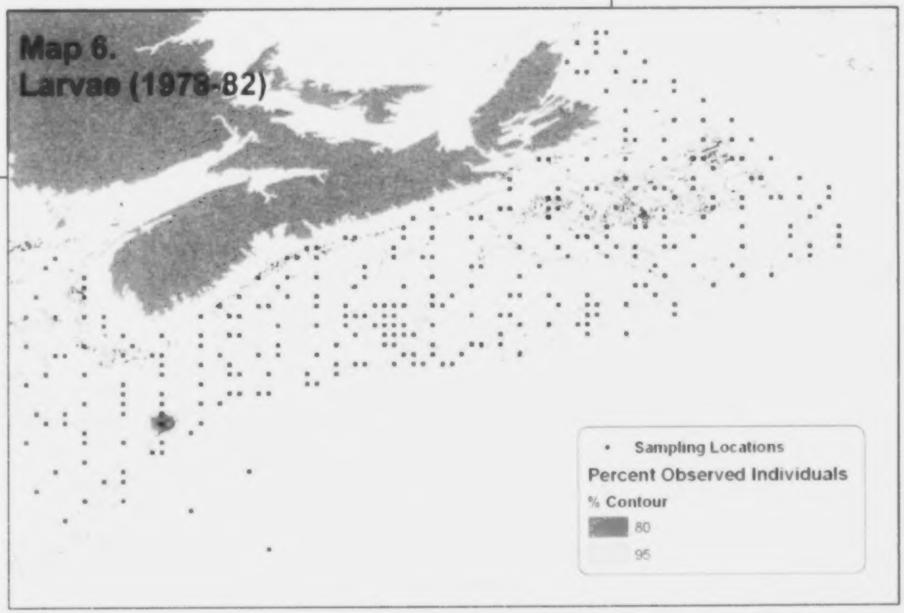
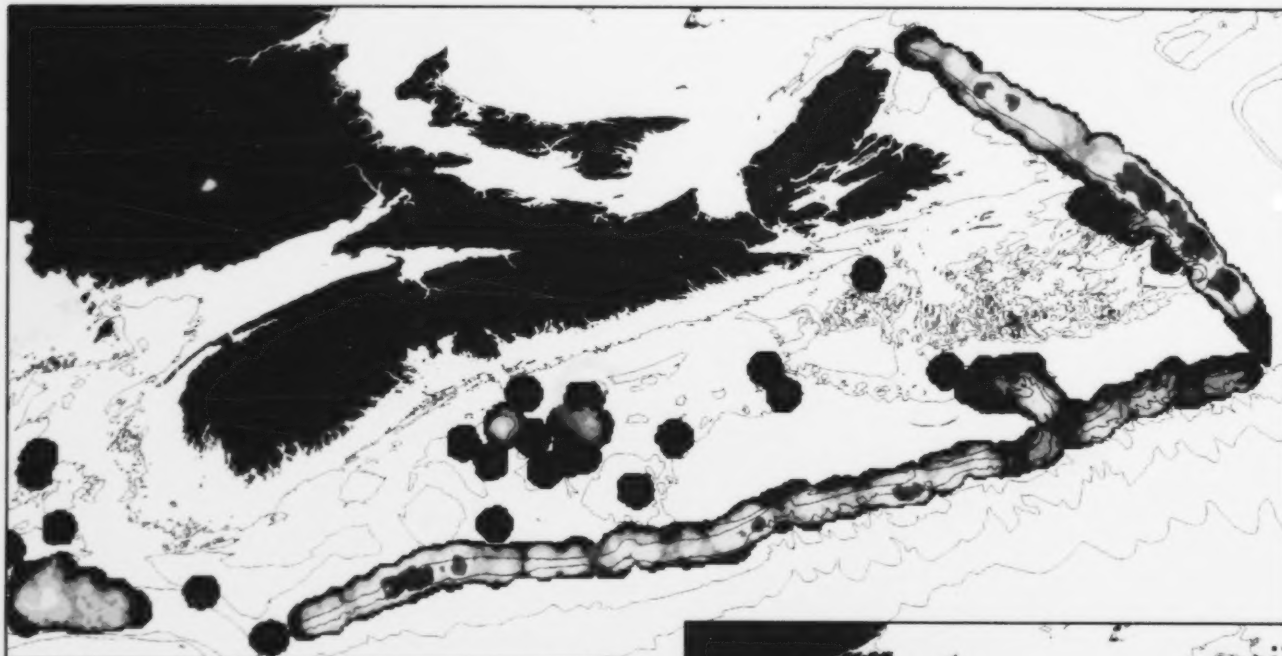


Figure 1. Population Trend



Longfin Hake (*Phycis chesteri*)



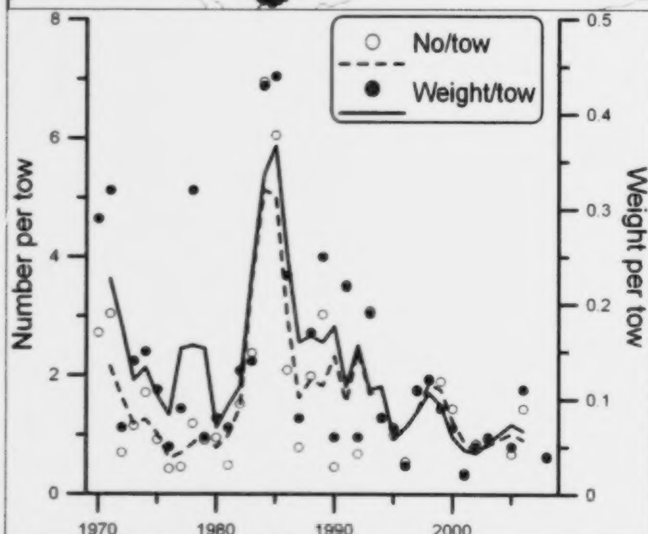
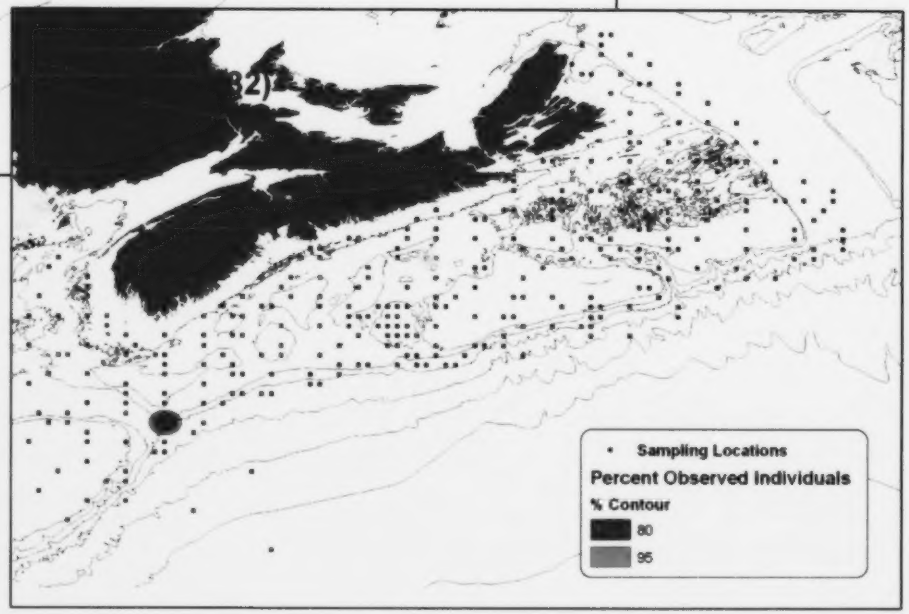


Figure 1. Population Trend



4.0 Discussion

4.1 Interpretation of the maps

The time period maps are intended to provide a better understanding about the areas of importance for many of the significant fish species on the Scotian Shelf. The four time period maps (Maps 1-4 for each species) provide information about the relative distribution of species during the summer months when the surveys are conducted. The summer survey reflects distribution during a rapid growth/feeding phase for northern temperate marine species. The distribution may, or may not change throughout the rest of the year, dependent on the species. The associated figures of population trends (Figure 1 for each species) are intended to provide the reader with insight about how the stratified mean numbers and biomass per tow have changed since the beginning of the RV survey. It is important to examine the pattern between the population trends and the ranked maps. In some cases top ranking areas expand while the population trend shows decreases in numbers and/or weight (e.g. Northern Shortfin Squid) while in other cases the areas expand with increases in population (*e.g.* Herring, Sandlance).

The time periods selected for the maps roughly correspond to changes in fishery management. These maps illustrate how the relative biomass of the species changed from one period to another. In some cases localized declines in relative biomass can be observed from these maps (e.g., Atlantic Cod , Thorny Skate, Winter Skate and Atlantic Wolffish). In other cases expansion of high ranking areas of biomass appears to be occurring (e.g., red hake) despite a stable population trend. As explained in the introduction, directed fishing on an area of high density could deplete that area if it were not replenished. For species that may have been highly targeted and are now highly depleted, the resultant array of preferred habitat (map 5) may not reflect the true array. For that reason, the maps should be interpreted in the context of the status of the population and any other pertinent knowledge (e.g., historical fishing patterns). We emphasize that for species at risk, maps that represent habitat before significant population declines should be used to identify preferred habitat.

Maps of important habitat (Map 5 for each species) indicate areas that consistently remained important summer habitat for the species. Areas that receive a score of 36 or higher (darkest red on the maps) have been important habitat for that species since the trawl surveys began despite changes in population, management and environmental conditions.

The larval distribution maps allow the reader to judge the level of spatial consistency between larval and adult distributions.

4.2 Application of the maps

It is anticipated that these maps will provide important and relevant information to many of the initiatives for sustainable development and ecosystem-based management, including marine protected area planning, by providing managers and stakeholders with information about important habitat for the significant fish species of the Scotian Shelf.

5.0 Acknowledgements

We would like to thank Jim Simon and Peter Koeller for reviewing an earlier draft. We are grateful to Bob Branton and Jerry Black for their expertise in organizing the information and for providing the data.

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